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JULY, 1922

SOME ASPECTS OF THE USE OF THE ANNUAL RINGS OF TREES IN CLIMATIC STUDY[1]

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I. Affiliations

NATURE is a book of many pages and each page tells a fascinating story to him who learns her language. Our fertile valleys and craggy mountains recite an epic poem of geologic conflicts. The starry sky reveals gigantic suns and space and time without end. The human body tells a story of evolution, of competition and survival. The human soul by its scars tells of man's social struggle.

The forest is one of the smaller pages in nature's book, and to him who reads it too tells a long and vivid story. It may talk industrially in terms of lumber and firewood. It may demand preservation physiographically as a region conserving water supply. It may disclose great human interests ecologically as a phase of plant succession. It may protest loudly against its fauna and parasites. It has handed down judicial decisions in disputed matters of human ownership. It speaks everywhere of botanical language, for in the trees we have some of the most wonderful and complex products of the vegetable kingdom.

The trees composing the forest rejoice and lament with its successes and failures and carry year by year something of its story in their annual rings. The study of their manner of telling the story takes us deeply into questions of the species and the individual, to the study of pests, to the effects of all kinds of injury, especially of fire so often started by lightning, to the closeness of grouping of the trees and to the nearness and density of competing

[1] Address of the President of the Southwestern Division of the American Association for the Advancement of Science, Tucson, Arizona, January 26, 1922.

vegetation. The particular form of environment which interests us here, however, is climate with all its general and special weather conditions. Climate is a part of meteorology, and the data which we use are obtained largely from the Weather Bureau. Much helping knowledge needed from meteorology has not yet been garnered by that science. For example, the conditions for tree growth are markedly different on the east and west sides of a mountain or on the north and south slopes. The first involves difference of exposure to rain-bearing winds, and the second means entirely different exposure to sun and shade. The latter contrast has been studied on the Catalina Mountains by Forrest Shreve. Again, the Weather Bureau stations are largely located in cities and therefore we can not get data from proper places in the Sierra Nevada Mountains of California, where the Giant Sequoia lives. Considering that this Big Tree gives us the longest uninterrupted series of annual climatic effects which we have so far obtained from any source, it must be greatly regretted that we have no good modern records by which to interpret the writing in those wonderful trees, and, so far as I am aware, no attempt is yet being made to get complete records for the future.

In reviewing the environment, one must go another step. One of the early results of this study was the fact that in many different wet climates the growth of trees follows closely and sometimes fundamentally certain solar variations. That means astronomical relationship. It becomes then an interesting fact that the first two serious attempts to trace climatic effects in trees were made by astronomers. I do not know exactly what inspired Professor Kapteyn, the noted astronomer of Groningen, Holland, to study the relation of oak rings to rainfall in the Rhineland, which he did in 1880 and 1881 (without publishing), but for my own case I can be more explicit. It was a thought of the possibility of determining variations in solar activity by the effect of terrestrial weather on tree growth. This, one notes, assumed an effect of the sun on our weather, a view which was supported twenty years ago by Bigelow.

But the possible relationship of solar activity to weather is a part of a rather specialized department of astronomical science, called astrophysics. And there is a great deal of help which one wants from that science, but which one can not yet obtain; for example, the hourly variations in the solar constant. I would like to know whether the relative rate of rotation and the relative temperatures of different solar latitudes vary in terms of the 11-year sunspot period. These questions have to do with some of the theories proposed in attempting to explain the sunspot periodicity.

We do not know the cause of the 11-year sunspot period. Here then is work for the astronomers.

Yet another important contact has this study developed. The rings in the beams of ancient ruins tell a story of the time of building, both as to its climate and the number of years involved and the order of building. This is anthropology. It will be mentioned on a later page.

Viewed through the present perspective, there is one way of expressing the entire work which shows more clearly its human end, a contact always worth emphasizing. If the study works out as it promises, it will give a basis of long-range weather forecasting of immense practical value for the future and of large scientific value in interpreting the climate of the past. This statement of it carries to all a real idea of the central problem.

II. Yearly Identity of Rings

The one fundamental quality which makes tree rings of value in the study of climate is their yearly identity. In other words, the ring series reaches its real value when the date of every ring can be determined with certainty. This is the quality which is often taken for granted without thought and often challenged without real reason. The climatic nature of a ring is its most obvious feature. There is a gradual cessation of the activity of the tree owing to lowered temperature or diminished water supply. This causes the deposition of harder material in the cell walls, producing in the pine the dark hard autumn part of the ring. The growth practically stops altogether in winter and then starts off in the spring at a very rapid rate with soft white cells. The usual time of beginning growth in the spring at Flagstaff (elevation 7,000 feet) is in late May or June and is best observed by Dr. D. T. MacDougal's "Dendrograph," which magnifies the diameter of the tree trunk and shows its daily variations. This spring growth depends upon the precipitation of the preceding winter and the way it comes to the tree. Heavy rains have a large run-off and are less beneficial than snow. The snow melts in the spring and supplies its moisture gradually to the roots as it soaks into or moves through the ground. There is evidence that if the soil is porous and resting on well cracked limestone strata, the moisture passes quickly and the effect is transitory, lasting in close proportion to the amount of rain. Trees so placed are "sensitive" and give an excellent report of the amount of precipitation. Such condition is commonly found in northern Arizona over a limestone bed rock. If the bed rock is basalt or other igneous material the soil over it is apt to be clay. The rock and the clay sometimes hold water until the favorable season is past and the tree growth de-

pends in a larger measure on other factors than the precipitation. For example, the yellow pines growing in the very dry lava beds at Flagstaff show nearly the same growth year after year. It is sometimes large, but it has little variation. Such growth is "complacent."

Yearly identity is disturbed by the presence of too many or too few rings. Surplus rings are caused by too great contrast in the seasons. The year in Arizona is divided into four seasons, two rainy and two dry. The cold rainy or snowy season is from December to March, and the warm tropical summer, with heavy local rainfall, occurs in July and August. Spring and autumn are dry, the spring being more so than the autumn. If the snowfall of winter has not been enough to carry the trees through a long dry spring, the cell walls in June become harder and the growing ring turns dark in color as in autumn. Some trees are so strongly affected that they stop growing entirely until the following spring. A ring so produced is exceptionally small. But others near-by may react to the summer rains and again produce white tissue before the red autumn growth comes on. This second white-cell structure is very rarely as white as the first spring growth and is only mistaken for it in trees growing under extreme conditions, such as at the lowest and dryest levels which the yellow pines are able to endure. Such is the condition at Prescott or at the 6,000-7,000 ft. levels on the mountains about Tucson. A broken and scattered rainy season may give as many as 3 preliminary red rings before the final one of autumn. In a few rare trees growing in such extreme conditions, it becomes very difficult to tell whether a ring is formed in summer or winter (that is, in late spring or late autumn). Doubling has become a habit with that particular tree—a bad habit—and the tree or large parts of it cannot be used for the study of climate.

But let us keep this clearly in mind: This superfluous ring formation is the exception. Out of 67 trees collected near Prescott, only 4 or 5 were discarded for this reason. Out of perhaps two hundred near Flagstaff, none have been discarded for this reason. Neodly a hundred yellow pines and spruces from northwestern New Mexico have produced no single case of this difficulty. The sequoias from California, the Douglas firs from Oregon, the hemlocks from Vermont and the Scotch pines from north Europe give no sign of it. On the other hand, 10 out of 16 yellow pines from the Santa Rita Mountains south of Tucson have had to be discarded and the junipers of northern Arizona have so many suspicious rings that it is almost impossible to work with them at all. Cypress trees also give much trouble.

The other difficulty connected with yearly identity is the omission of rings. Missing rings occur in many trees without lessening the value of the tree unless there are extensive intervals over which the absence produces uncertainty. A missing ring here and there can be located with perfect exactness and causes no uncertainty of dating. In fact, so many missing rings have been found after careful search that they often increase the feeling of certainty in the dating of rings.

Missing rings occur when autumn rings merge together in the absence of any spring growth. This rarely if ever occurs about the entire circumference of the tree. There are a few cases in which, if the expression may be excused, I have traced a missing ring entirely around a tree without finding it. I have observed many cases in which the missing ring has been evident in less than 10 per cent. of the circumference. Some are absent in only a small part of their circuit. I have observed change in this respect at different heights in the tree, but have not followed that line of study further. It is beautifully shown in the longitudinally bisected tree.

One sees from this discussion what the probable errors may be in mere counting of rings. In the first work on the yellow pines the dating was done by simple counting. Accurate dating in the same trees (19 of them) later on showed that the average error in counting through the last 200 years was 4 per cent., due practically always to missing rings. A comparison in seven sequoias between very careful counting and accurate dating in 2,000 years shows an average counting error of 35 years, which is only 1.7 per cent.

Full confidence in yearly identity really comes from another source. The finding of similar distribution of large and small rings in practically all individuals of widely scattered groups of trees over great periods of time has been evidence enough to make us sure. This comparison process of groups of rings in different trees has received the rather clumsy name of "cross-identification." Cross-identification was first successful in the 67 Prescott trees, then was carried across 70 miles to the big Flagstaff groups. Later it was found to extend 225 miles further to southwestern Colorado with extreme accuracy, 90 per cent. perhaps. This is over periods of more than 250 years. Catalina pines from near Tucson have a 50 per cent. likeness to Flagstaff pines. There are many points of similarity in the last 200 years and many differences. Santa Rita pines are less like the Flagstaff pines than are the Catalinas. In comparison with the California sequoias, differences become more common. The superficial resemblance to Arizona pines is 5 or 10

per cent. only. That is, out of every 10 or 20 distinctive rings with marked individuality, one will be found alike in California and Arizona. For example, A. D. 1407, 1500, 1580, 1632, 1670, 1729, 1782, 1822 and 1864 are small in Arizona pines and California sequoias. While only a few extreme individual years thus match, there are correspondences in climatic cycles to which attention will be called later.

Cross-identification is practically perfect amongst the sequoias stretching across 15 miles of country near General Grant National Park. Trees obtained near Springville, some 50 miles south, show 50 to 75 per cent. resemblance in details to the northern group. This was far more than enough to carry exact dating between these two localities. Cross-identification in some wet climate groups was extremely accurate. A group of 12 logs floating in the river-mouth at Geffle, Sweden, showed 90 to 95 per cent. resemblance to each other. The range was 100 to 200 years and there were no uncertain years at all. The same was true of some 10 tree sections on the Norwegian coast and of 13 sections cut in Eberswalde in Germany. A half dozen sections cut in a lumber yard in Munich did not cross-identify with each other. A group of 5 from a lumber yard in Christiania was not very satisfactory. The vast majority, however, have been absolutely satisfactory in the matter of cross-identification. Nothing more is needed to make the one ring a year ideal perfectly sure, but if there were, it would come in such tests as frequently occur in checking the known date of cutting or boring, with a set of rings previously dated. That has been done on many occasions in Arizona and California. To give final assurance, the record in the yellow pine was compared with statements of good and bad years, and years of famine, flood and cold, reported in Bancroft's "History of Arizona and New Mexico," and it was found that his report identified with the character of the growth in the corresponding years of the trees.

Three results may be noted before leaving this important subject. Deficient years extend their character across country with more certainty than favorable years. A deficient year makes an individual ring small compared to those beside it. Large rings, on the other hand, are more apt to come in groups and so do not have quite the same individuality. Nor are they as universal in a forest. If they occur at a certain period in one tree, the chances are about 50 per cent. that the corresponding years in the neighboring trees will be similarly enlarged. If, however, a very small ring occurs in a tree, the chances are over 90 per cent. that the neighboring trees will show the same year small.[2]

Second, with many groups of trees where the resemblance be-

tween their rings is strikingly exact, a small number of individuals such as 5 will answer extremely well for a record, and even fewer will give valuable and reliable results. But the central part of a tree has larger growth and is less sensitive than the outer part. Its character is somewhat different. To get a satisfactory representation through several centuries, therefore, it is better to combine younger trees with older ones to get a more even and constant record of climatic conditions.

The third thought is this. The spreading of a certain character over many miles of country stamps it in almost every case as climatic in origin, because climate is the common environment over large areas.

III. Number and Location of Trees

The whole number of trees used is nearly 450 and includes cone-bearing trees from Oregon, California, Arizona, New Mexico, Colorado, Vermont, England, Norway, Sweden, Germany and Bohemia. The total number of rings dated and measured is well over 100,000. The average ages found in these various trees are very interesting. The European groups reach for the most part about 90 years, although one tree in Norway showed 400 years of age, and 15 were found beginning as early as 1740. The Oregon group of Douglas firs goes back to about 1710, the Vermont hemlocks reach 1654, the Flagstaff yellow pines give a number of admirable records from about 1400.

The oldest trees, of course, were the great sequoias from the Sierra Nevada Mountains in California. They were found to have ages that formed natural groups, showing probably a climatic effect. There are very few under 700 years old (except the young ones which have started since the cutting of the Big Trees). A number had about that age. The majority of the trees scatter along in age from 1,200 up to about 2,200 years, at which age a large number were found, one or two were found of 2,500 years, one of 2,800, one of 3,000, one at just under 3,100, and the oldest of all just over 3,200. The determination of this age of the older sequoias in the present instance is not merely a matter of ring counting, but depends upon the inter-comparison of some 55,000 rings in thirty-five trees. In 1919 a special trip was made to the Big Trees and samples from a dozen extra trees obtained in order to decide the case of a single ring, 1580 A. D., about which there was some doubt, and it was apparent that the ring in question stood for an extra year. This was corrected and it now seems likely that there is no

[2] This success in cross-identification applies to the groups examined. A recent group of coast redwoods from Santa Cruz, California, present a multitude of difficulties.

mistake in dating through the entire sequence of years, but if not correct the error is certainly very small.

IV. Topography

The late Professor W. R. Dudley of Stanford University in his charming essay on the "Vitality of the Sequoia" refers to the fact that the growth of the Big Trees depends in a measure on the presence of a brook near by. This agrees with my own observations. Size is far from a final indication of age. The General Grant tree which has no running water near it and is the largest in the Park of that name, has a burnt area on one side in which the outer rings are exposed, allowing an estimate of its average rate of recent growth. From much experience with the way the sequoia growth is influenced by age, it was possible to assign 2,500 years as the approximate time it took this giant to reach its present immense diameter of close to 30 feet. But about three miles west near a running brook is a stump which is over twenty-five feet in diameter, but is only about 1,500 years old. That is the effect of contact with an unfailing source of water.

Perhaps the most general characteristic which stands out in the different groups of dry-climate trees is a close relationship of this kind between the topography and the growth produced. For that reason, I have visited the site of every dry-climate group and indeed have examined the stumps of almost every tree in my collection.

It was found that dry-climate trees which grew in basins with a large and constant water supply, and this refers especially to the sequoias, usually produced rings without much change in size from year to year. This character of ring is called "complacent." The opposite character is the "sensitive" ring where a decided variation is shown from year to year. Sensitive trees grow on the higher elevations where the water supply is not reliable and the tree must depend almost entirely on the precipitation during each year. Such trees grow near the tops of ridges or are otherwise separated from any collection of water in the ground. In case of the basin trees, one could be sure that a ring was produced every year, but owing to the lack of individuality in the rings for certain years, it was difficult to compare trees together and produce reliable data. In case of the sensitive tree growing in the uplands there was so much individuality in the rings that nearly all of the trees could be dated with perfect reliability, but in extreme cases the omission of rings in a number of trees required special study. Of course, these cases were easily settled by comparison with other trees growing in intermediate localities.

Trees growing in the dry climate of Arizona at an altitude where they have the utmost difficulty in getting water to prolong life become extraordinarily sensitive. In the same tree one finds some rings several millimeters across and others microscopic in size or even absent.

In order to express this different quality in the trees a criterion called mean sensitivity is now under investigation. It may be defined as the difference between two successive rings divided by their mean. Such quotients are averaged over each decade or other period desired and are believed to depend in part on the relative response of the trees to climatic influences. The great sensitiveness of the yellow pines as compared with the best sequoias is evident in any brief comparison of dated specimens.

V. Instruments

In the course of this long attention to the rings of trees and in studying such a vast number of them, special tools to secure material and to improve and hasten the results have very naturally been adopted or developed. One goes into the field well-armed, carrying a flooring saw with its curved edge for sawing half across the tops of stumps, a chisel for making numbers, numerous paper bags for holding fragments cut from individual trees, a recording note book, crayon, a shoulder bag, camera and especially a kindly, strong-armed friend to help in the sawing. In the last eighteen months the Swedish increment borer has been used extensively to get records from living pine trees. Hard woods and juniper are too tough. It has previously been considered that the little slender cores, smaller than a pencil, so obtained, would hardly be worth working on. But the method of mounting them has been raised to such a degree of efficiency, and the collection of material becomes so rapid that the deficient length and the occasional worthless specimen are counterbalanced. Besides, it is often easy to supplement a group of increment cores by some other form of specimen extending back to greater age. The Mount Lemmon group, near Tucson, has eight cores giving a good record from about 1725 to the present time; a saw cutting from a large stump in Summerhaven carries the record back 150 years earlier. It should, however, be supported by at least one more long record and this can be done by the tubular borer described next.

The tubular borer was designed especially for the dried and sometimes very hard logs in the prehistoric ruins. It works well on pine trees and junipers. It gives a core an inch in diameter, which means a far better chance of locating difficult rings than in the increment borer cores which are only one fifth of that diameter. The borer is a one-inch steel tube with small saw-teeth on one

end and a projection at the other for holding in a common brace. A chain drill attachment is also provided to help in forcing the drill into the wood. The difficulty with this borer is the disposal of sawdust and the extraction of the core. For the former, a separate hole is bored with a common auger just below the core (if in an upright tree) and in advance of it to catch the sawdust. The core is broken off every three inches and pulled out to make more room for the sawdust. To extract the core a small steel rod is provided with a wedge at one end and a screw at the other. One- and two-foot tubes are carried so that it is possible to reach the centers of most pine trees. It would not be difficult to develop an instrument much more efficient than this and it should be done. Soon a borer will be needed to pass through a 35-foot tree or to sound the depths of the great Tule trees of southern Mexico.

The tools just mentioned are technical, yet in no sense complex. A measuring instrument has just been completed whose usefulness will be extensive and whose details of construction are too complex for present description. It is for measuring the width of rings. It makes a record as fast as one can set a micrometer thread on successive rings. The record is in the form of a plot drawn in ink to scale on coordinate paper so that the values can be read off from it at once for tabulation. This form of record was desired because individual plots have long been made to help in selecting the best trees and in studying their relation to topography. The instrument as constructed magnifies 20, 40 or 100 times, as desired. It can be attached to the end of an astronomical telescope and used as a recording micrometer capable of making a hundred or more settings before reading the values. It seems possible that it will have other applications than the ones here mentioned.

Another instrument of entirely different type has been developed here since 1913. Its general principle has been published and will not be repeated, but in the last three years it has been entirely rebuilt in a more convenient form through the generosity of Mr. Clarence G. White of Redlands. This instrument is now known as the White Periodograph. It could be called a cycloscope or cyclograph. Its purpose is to detect cycles or periods in any plotted curve. It differs from previous instruments performing harmonic analysis in that it is designed primarily to untangle a complex mixture of fairly pronounced periods while others determine the constants of a series of harmonic components. For example, the periodograph can be applied to a series of rainfall records to find if there are any real periods operating in a confused mixture. It is also designed to get rid of personal equation and to get results quickly. The instrument as reconstructed is far more convenient

and accurate in use and has already given important results. It enables one to see characteristics in tree growth variation which are not visible to the unaided eye. It is specially arranged now to give what I have called the differential pattern or cyclogram because this pattern not only tells the periods or cycles when properly read but shows the variations and interferences of cycles and possible alternative readings. Tests on the accuracy of solutions by this instrument show that its results correspond in precision to least square solutions.

VI. Correlations

It is no surprise that variations in climate can be read in the growth rings of trees, for the tree ring itself is a climatic product. It is an effect of seasons. The geologists use the absence of rings in certain primitive trees as an indication that no seasons existed in certain early times. Whatever may have been the cause of that absence, we recognize that the ring is caused primarily by changes in temperature and moisture. Now if successive years were exactly alike, the rings would be all of the same size with some alteration with age and injury. But successive years are not alike and in that difference there may be some factor which appeals strongly to the tree. In northern Arizona, with its limited moisture and great freedom from pests and with no dense vegetable population, this controlling factor may reasonably be identified as the rainfall. If the trees have all the moisture they can use, as in north Europe about the Baltic Sea and other wet climates, we look for it in something else. It could be—I do not say that it is—some direct form of solar radiation. It could be some special combination of the ordinary weather elements with which we are familiar. Shreve has studied this phase in the Catalinas. If the abundance of moisture is so great as actually to drown the tree, then decrease in rainfall which lowers the water table below ground will be favorable. A fact often forgotten is that more than one factor may enter into the tree rings at the same time, for example, rainfall, temperature and length of growing season. These may be isolated in two ways. We may select a special region, as northern Arizona, where nature has standardized the conditions, leaving one of them, the rainfall, of especial importance. Or we may isolate certain relationships as in any other investigation, by using large numbers of observations, that is, many trees, and averaging them with respect to one or another characteristic. For example, I can determine the mean growth curve of the Vermont hemlocks and then compare it separately with rainfall and solar activity, and I may, and do, find a response to each. For that reason, I have felt quite justified in seeking first the correlation with moisture. A temperature cor-

relation doubtless exists and in fact has been noted, but its less minute observance does not lessen the value of the rainfall relationship.

The first real result obtained in this study was in 1906 when it became apparent that a smoothed curve of tree growth in northern Arizona matched a smoothed curve of precipitation in southern California since 1860. That degree of correlation is now extensively used in the Forest Service. This was followed almost at once by noting a strikingly close agreement between the size of individual rings and the rainfall for the corresponding years since 1898, when the Flagstaff weather station was established. The more detailed comparison between rainfall and ring growth was made with Prescott trees in 1911. Some 67 trees in five groups within ten miles of Prescott were compared with the rainfall at Whipple Barracks and Prescott which had been kept on record since 1867. The result was very interesting. For most years the tree variations agree almost exactly with the rainfall but here and there is a year or two of disagreement. The cause of these variable years will sometime be an interesting matter of study. Taken altogether the accuracy of the tree as a rain-gauge was 70 per cent. But a little allowance for conservation of moisture raised the accuracy to 85 per cent., which is remarkably good. The actual character of this conservation is not evident. At first thought it might be persistence of moisture in the ground, but the character of the mathematical formula which evaluated it allowed a different interpretation, namely, that in a series of poor years the vital activity of the tree is lessened. During the dry period from about 1870 to 1905 or so, the trees responded each year to the fluctuations in rainfall but with less and less spirit. This lessening activity took place at a certain rate which the meteorologists call the "accumulated moisture" curve. This suggested that the conservation was in the tree itself. There is much to be done in this comparison between tree growth and rainfall, but the obstacle everywhere is the lack of rainfall records near the trees and over adequate periods of time. The five Prescott groups showed that in a mountainous country nearness was very important. But the nearest records to the sequoias are 65 miles away and at 5,000 feet lower elevation. The best comparison records for the Oregon Douglas spruce are 25 miles away. It is so nearly everywhere. The real tests must be made with records nearby.

In 1912 while attempting to test this relationship of tree growth to rainfall in north Europe, I found that the Scotch pines south of the Baltic Sea showed a very strong and beautiful rhythm matching exactly the sunspot cycle as far back as the trees ex-

tended, which was close to a century. The same rhythm was evident in the trees of Sweden, and perhaps more conspicuous in spruce than pine. Near Christiania the pines were too variable to show it, but it reappeared on the outer Norwegian coast. To the south near the Alps it disappeared, and in the south of England it was uncertain but probably there. In this country it shows prominently in Vermont and Oregon, but the two American maxima come one to three years in advance of the sunspot maxima. There is evidently an important astronomical relationship whose meaning is not yet clear. It is to be noted that it appears in regions whose trees have an abundance of moisture and it thus appears to be a wet climate phenomenon.

But the correlations do not stop at rain and sunspot periodicity. The pines of northern Arizona which are so sensitive to rainfall show a strong half sunspot period. And on testing it one finds that the rainfall does the same and that these variations are almost certainly related to corresponding temperature variations and to the solar period. Thus, the Arizona trees are related to the weather and the weather is related in a degree at least to the sun. Thus we find evidence in forest trees that the 11-year sunspot period prevails in widely different localities and in many places constitutes the major variation. This introduces us to the study of periodic effects in general.

VII. Cycles

Considering first that cycles as we have just shown are revealed in tree growth, second, that the trees give us accurate historic records for hundreds and even thousands of years, and third, that simple cycles or even some more complex function could give a basis for long range weather forecasting, we recognize the vital importance of this elemental part of the story told by the trees. It was exactly for this purpose that the periodograph was designed and constructed and some ten score curves have been cut out for analysis, after minute preparation of the very best yearly values. In fact the major time for two years has been given to this preparation of material. It is hardly done yet, but it is far enough along to anticipate its careful study in the near future. Our present view may be profoundly modified, but it is safe to say that the sunspot cycle and its double and triple value are very general. The double value, about 22 years, has persisted in Arizona for 500 years, and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Brückner's cycle, has operated in Arizona for the last 200 years and in Norway for nearly 400 at least. A one-hundred-year cycle is very prominent throughout the 3,000 years of sequoia record and

also in the 500 years of yellow pine. An hypothesis covering all these sunspot multiples will be tested out in the coming months. Should a real explanation be found a step will have been made toward long-range prediction and an understanding of the relationship of the weather and the sun. Other periods, however, than the multiples of the sunspot period do occur and general analysis shows that different centuries are characterized by different combinations of climatic cycles. This suggests to us a great and interesting problem. If we can establish the way in which different regions act and react at the same time, then it may become possible to determine the age of an ancient buried tree by finding the combination of short cycles its rings display and then determining when this combination or its regional equivalent existed in our historic measuring tape, the great sequoia.

VIII. Prehistoric Records in Trees

A new method of investigating the relative age of prehistoric ruins has been developed in connection with this study of climate by the growth of trees, and is being applied to the remarkable ruins at Aztec, in northwestern New Mexico, with its 450 rooms, now in process of excavation by the American Museum of New York City. The ceilings were built of tree trunks placed across the width of the rooms. Smaller poles were laid across these beams and covered with some kind of brush and a thick layer of earth. The beams used in this ceiling construction are almost entirely of yellow pine or spruce and for the most part are in good condition. Many of the rooms have been hermetically sealed for centuries. The beams which have been buried in dust or adobe or in sealed rooms are well preserved. Only those which have been exposed to the air are decayed.

In 1915 Dr. Clark Wissler of the American Museum offered sections of such beams for special study of the rings, knowing the writer's work upon climatic effects in the rings of trees. This offer was gladly accepted, and some preliminary sections were sent at once from the Rio Grande region. These first sections showed that the pines and spruces were far better than cedars for determining climatic characteristics.

The next lot of sections came from Aztec and was cut from loose beams which had been cleared out of the rubbish heaps. Six of these sections cross-identified so perfectly that it was evident that they had been living trees at the same time. This success led to my visit to Aztec in 1919 and a close examination of this wonderful ruin. It was at once apparent that an instrument was necessary for boring into the beams to procure a complete sample of the rings from center to outside, and that the process must avoid

injuring the beams in any way. Such an instrument was developed in the tubular borer as already described. This tool was sent to Mr. Morris and during 1920 he bored into all the beams at Aztec then available and sent me the cores.

These cores, together with other sections of beams too frail for boring, finally represented 37 different beams in some 20 different rooms scattered along the larger north part of the ruin. Practically all of these show similar rings near the outside, and by counting to the last growth ring of each it was easy to tell the relative dates at which the various timbers were cut.

In order to help in describing given rings in these various sections, a purely imaginary date was assumed for a certain rather large ring which appeared in all the timbers. This was called R. D. (Relative Date) 500, and all other rings earlier or later are designated by this system of relative dates. Many interesting results were evident as soon as the various relative dates were compared. In the first place, instead of requiring many hundreds of years in construction as any one would suppose in looking at the ruin, the larger part of it was evidently erected in the course of ten years, for the dates of cutting the timbers found in the large north side include only eight or nine years. The earliest timbers cut were in the northeast part of the structure. The later timbers are at the northwest, and it is evident that the sequence of building was from the easterly side to the westerly side, ending up with the westerly end and extending toward the south.

In one place beams from three stories, one over the other, were obtained. The top and bottom ceiling timbers were cut one year later than those of the middle ceiling, showing that in vertical construction the three floors were erected in immediate succession. A floor pole from Pueblo Bonito was cut one year later than the latest beam obtained from that ruin.

An even more interesting fact was soon after disclosed. A study of the art and industries of neighboring ruins had satisfied Mr. Nelson and Mr. Morris of the American Museum that some of the ruins in Chaco Canyon, some 50 miles to the south, were not far different in age from those at Aztec. The only beams immediately available from the Chaco Canyon ruins had been collected in the Pueblo Bonito ruin 25 years before by the Hyde expedition. Accordingly sections were cut from seven beams which this expedition had brought back to New York City. One of these sections was a cedar and has not yet been interpreted, but the others were immediately identified in age both among themselves and with reference to the Aztec timbers. It was found that these Pueblo Bonito beams were cut within a few years of each other at a time preceding the

cutting of the timbers at Aztec by 40 to 45 years. Many of the timbers of each ruin were living trees together for more than one hundred years and some even for two hundred years, and there seems no possible doubt of the relative age here determined. This result showing that a Chaco Canyon ruin was built nearly a half century before Aztec is the first actual determination of such a difference in exact years. A single beam from Peñasco, some 14 miles down the Chaco Canyon from Pueblo Bonito showed that its building was intermediate between Pueblo Bonito and Aztec.

Another association of growth rings with prehistoric deposits has rapidly developed in the last two years. In 1904 the writer discovered an Indian burial at a depth of eight feet in a cultivated field near Flagstaff, Arizona. A skeleton and two nests of pottery were revealed by a deep cut which a stream of water had made through the land. Near the burial was an ancient pine stump standing in place 16 feet underground. The tree was later discovered by a neighbor and became part of a bridge support. The Indian remains were given away except a red bowl of simple pattern and a good piece of black and white ware which is now in the Arizona State Museum. In 1920 the search for these buried trees was resumed and more than a half dozen in excellent preservation were found at depths from four to twelve feet. Mr. L. F. Brady of the Evans School gave most important help in getting out sections of these. In the summer of 1921 he again resumed the search and found several more buried trees and especially determined several levels at which pottery and other Indian remains are plentiful. These buried trees have been preserved by their pitch and show here and there quantities of beautiful little white needle-shaped crystals, which Dr. Guild has discovered to be a new mineral and to which he has given the name "Flagstaffite."

Several conclusions are already evident in the study of these buried trees. In the first place they supply much desired material from which some data regarding past climates may be obtained. The trees buried most deeply have very large rings and a certain kind of slow surging in ring size. Both of these features are characteristic of wet climates. The stumps at higher levels show characters common in dry climates, that is, general small rings and a certain snappy irregularity with frequent surprises as to size. This variation with depth gives a strong intimation of climatic change. The cycles dominant at these different levels also may be read from these sections and are likely to prove of great value.

In the second place this material will help in determining the age of the Indian remains and perhaps even of the valley filling in which these objects were located. There are several ways of

getting at this which will take time in working out but there is one inference immediately evident. One log was buried only eighteen inches, yet its rings do not tally with the 500 years of well determined rings of modern trees in that neighborhood. Allowing about a century for the sap-wood lost from the buried tree and a half century more necessary to detect cross-identity, we have an approximate minimum of 350 years for that foot and a half of depth. The age of Indian relics at four and even nine feet must be very considerable.

These then are the first results of the application of the general study of tree rings to archeological work and suggest further possibilities. Not only does it seem probable that this beginning of relative chronology of the wonderful ruins of the Southwest will be extended to include other ruins in this region, but this study of the prehistoric writing in trees will help in the clearer understanding of the climatic conditions which existed in those earlier times when the largest bona fide residences in the world were being built.

IX. Conclusion

The economic value of this study of tree rings and climate is to be found in the possibility of long-range weather forecasting. In non-economic terms we are trying to get the inter-relationships between certain solar and terrestrial activities by the aid of historical writing in the trees. The work is not done; a wide door is open to the future. Hence it is impossible to make an artistic conclusion. There is no real conclusion yet. Some definite results have been reached and they encourage us to hope for larger returns in the future. Through this open door we can see attractive objectives looming above us and we note the outlines of some of the hills to be surmounted. To climb these metaphorical hills we need groups of trees from all parts of this country, from numerous specially selected spots and areas, from distant lands; we need ancient tree records from Pueblo ruins and modern Hopi buildings, from mummy case and viking ship, from peat-bog and brown-coal mine, from asphalt bed and lava burial and from all ancient geologic trees in wood and stone and coal. We need measuring instruments, workers, museum room for filing and displaying specimens. And we need great quantities of climatic data obtained with special reference to tree comparison. With all this and with a spirit behind it, we shall quickly read the story that is in the forest and which is already coming to us through the alphabet of living trees.

VARIABILITY VS. UNIFORMITY IN THE TROPICS

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It is commonly stated that tropical climates are extremely uniform. This is only partly true. They indeed have comparatively slight seasonal variations in temperature and in the length of day and night, and large areas have rather steady winds much of the time. But continual emphasis upon the uniformity of tropical climates is misleading because there are important variations in temperature and wind, while the rainfall of the lower latitudes appears to be more variable on the average than the rainfall of higher latitudes. There likewise appears to be more variation in storminess and in rapid change of air pressure than in higher latitudes.

Recent field investigations (financed by the Bishop Museum of Honolulu and Yale and Indiana Universities) in Hawaii, Fiji, tropical Australia, the East Indies, the Philippines and tropical China, and examination of official meteorological records concerning these areas and others have disclosed interesting evidences of tropical variability and have convinced me that the conventional statements, based on averages, are sufficiently misleading to make it worth while to emphasize the climatic variability occurring in the tropics.

The small seasonal contrasts in temperature which are characteristic of the tropics are perhaps the chief reason why the impression has been gained that tropical climates are uniform in other respects. Another reason for this common belief is the fact that the climatic data concerning the tropics are chiefly available in the form of averages. Averages by themselves are very misleading and should be supplemented as soon as possible by statements as to extremes, and as to normal extent of departure from means.

Although the average seasonal range in temperature is indeed small in low latitudes as compared with middle latitudes, there is an appreciable seasonal contrast in latitudes more than 10° or 15° from the equator. Indeed some parts of the tropics have about as great a seasonal range of temperature as certain especially uniform parts of higher latitudes. This is illustrated when the average

differences in mean temperature between the three warmest months and the three coolest of the following pairs of seaport cities are compared. Some of the cities in the right-hand column are not within the tropics according to the narrowest limitation of that zone. However, all are within the belt dominated by the Trades during most of the year, which is the belt commonly considered as tropical.

TABLE 1
SEASONAL RANGE OF TEMPERATURE

Calcutta,	range 18° F., vs.	Dublin,	range 17° F.,	22° N. vs. 53° N.
Hongkong,	range 20° F., vs.	Glasgow,	range 12° F.,	22° N. vs. 56° N.
Brisbane,	range 17° F., vs.	Hobart, Tas.	range 15° F.,	27° S. vs. 43° S.
Durban,	range 11° F., vs.	Dunedin, N. Z.,	range 14° F.,	29° S. vs. 46° S.
Cairo,	range 16° F., vs.	Bergen, Nor.,	range 22° F.,	30° N. vs. 60° N.
New Orleans,	range 26° F., vs.	Vancouver,	range 22° F.,	30° N. vs. 49° N.
Madras,	range 9° F., vs.	San Francisco,	range 8° F.,	13° N. vs. 38° N.
Naples,	range 25° F., vs.	London,	range 22° F.,	41° N. vs. 51° N.

Even in regard to extremes of temperatures, some cities in fairly low latitudes have ranges which approach those of the less variable parts of the relatively high latitudes. This is illustrated by the following table showing the difference between the highest and lowest temperatures ever officially recorded at certain pairs of seaport cities up to a recent year.[1]

TABLE 2
EXTREME RANGE OF TEMPERATURE

Calcutta,	range 64° F., vs.	Dublin,	range 74° F.,	22° N. vs. 53° N.
Hongkong,	range 65° F., vs.	Glasgow,	range 78° F.,	22° N. vs. 56° N.
Bombay,	range 54° F., vs.	Lisbon,	range 62° F.,	19° N. vs. 40° N.
Madras,	range 55° F., vs.	San Francisco,	range 72° F.,	13° N. vs. 38° N.
Rio de Janeiro,	range 52° F., vs.	Wellington,	range 58° F.,	23° S. vs. 42° S.
Brisbane,	range 73° F., vs.	Hobart, Tas.,	range 78° F.,	27° S. vs. 43° S.
Durban,	range 71° F., vs.	Dunedin, N. Z.,	range 71° F.,	29° S. vs. 46° S.
Cairo,	range 82° F., vs.	Bergen, Nor.,	range 84° F.,	30° N. vs. 60° N.
New Orleans,	range 95° F., vs.	Sitka,	range 90° F.,	30° N. vs. 57° N.
Capetown,	range 68° F., vs.	Amsterdam,	range 86° F.,	34° N. vs. 52° N.

That there are appreciable seasonal contrasts in temperature in lower latitudes is not surprising when the seasonal variation in insolation is considered. In spite of the fact that the sun shines vertically somewhere between the two tropics every day in the year, there is a great change in angle of incidence. Few people realize that when the sun is vertically over the northern tropic

[1] References to sources of data are given in a longer, more technical article on "Variability of Tropical Climates" to be published in *The Geographical Journal* (London).

(Cancer), it shines upon the southern tropic (Capricorn) less nearly vertically by 4 degrees than upon the Arctic Circle. The latitude of New York receives much more heat from the sun on June 21 than does the equator, for not only is the sun six degrees more nearly vertical than at the equator, but moreover the days are almost four hours longer.

Although on the average tropical regions show less contrast in seasonal change of temperature than do middle latitudes, the reverse is true in respect to daily range. The night has been called the winter of the tropics. The daily range is considerable in all lower latitudes, although it is less in the more humid regions than in the more arid. On the average it is distinctly greater than the normal range in higher latitudes. This is due to two chief influences: Day and night are more nearly equal in length, and hence there is a closer balance between the duration of the heating and cooling periods than occurs in higher latitudes, where the nights are too short in summer for marked cooling and the days are too short in winter for effective heating. The other great cause is the higher average temperature, since the escape of heat varies as the fourth power of the absolute temperature. This means that normally there is much greater cooling per nocturnal hour wherever the day-time temperature is high than where it is low. A third reason why the diurnal range averages greater in low latitudes (below 30°) is that a larger proportion of the area is arid or semi-arid than is the case in middle latitudes.

In the tropics the nights often become so cool that considerable discomfort results. Even in an insular climate like that of Suva, Fiji (latitude 18°S.), in spite of the wind blowing off the sea, and a rainfall of over 100 inches fairly evenly distributed throughout the year, it commonly becomes so cool at night that the sensitive residents wear wraps if they walk out late in the evening. Indeed, even the heavy army overcoats are frequently worn with comfort at night and in the early morning during the cooler season. In drier parts of the tropics, the nights become much cooler than in a humid locality like Suva. On the dry western sides of the Fiji Islands, for example, temperatures below 40°F. have been recorded near latitude 16° close to sea level, and in dry continental areas frost is not unknown near sea level, as for example within 20° from the equator in Australia and Africa.

Another type of marked cooling in the tropics is the sudden drop, often as much as 6° or 8°F., which occurs in thunder-storms, which are very frequent in many parts of the tropics, far commoner on the average than in higher latitudes. Sometimes, as when hail falls in quantity, the temperature-drop is much greater.

Hail storms are not very rare in some tropical localities. For example, ten hail storms were reported in ten years in latitudes 13° to 16° S., near sea level in the Northern territory of Australia. Three hail storms occurred in Panama (latitude 9°) in a twelve year period.

Cold snaps of still other types occur within the tropics. For instance, cold winds sometimes sweep down from higher latitudes and bring low temperatures surprisingly near the equator. Zero temperatures have been officially recorded in subtropical Northern Florida (lat. 30° N.), and a temperature of only 10° above zero F. has occurred on the Gulf Coast of Mexico in latitude 25½° N. Central coastal Queensland is subject to "severe frosts" during four months in the year within 21° of the equator, while freezing temperatures have occurred even in the day time in southeastern Asia in latitude 22° at sea level. Still farther south, on the China Sea near Manila, latitude 15°, for example, northerly gales in winter occasionally make overcoats welcome even in the day time. Similar cold snaps occur in the cooler months in other tropical localities such as the Hawaiian Islands, Jamaica and Fiji. Indeed, remarkable as it may seem, the Weather Bureau reports a snow flurry practically at sea level at Mahukona, Hawaii (lat. 20° 11′), lasting ten minutes on December 29, 1921. Perhaps even more surprising is the great cooling reported as not rare in winter on the coast of Venezuela, in latitude 10° N. Director Ugueto, of the Cajigal Observatory, announces that gales from the north off the sea occasionally bring temperatures of 45° F. or even less, in the day time, lasting a number of days. They are not associated with thunderstorms, for the sky is clear at the time.

Because of the sensitiveness of the residents of the tropics to low temperatures, chills and colds often develop and sometimes pneumonia. Many observers have been impressed by the abundance of coughs and catarrh in the tropics. They may be more common there than in Canada. Indeed there is considerable truth in the saying that "cold causes more suffering in the tropics than in polar or subpolar regions."

Now as to the winds: Five chief sorts of variation within the tropics merit attention: (1.) Even when the direction is fairly constant, there is a marked diurnal variation in velocity. Calm nights are the rule in trade wind deserts and nearly calm nights are common elsewhere on the land except upon exposed elevations. Likewise at sea, while the diurnal range is less than on land, it is notable. For example, Tetens reports a diurnal range of over 50 per cent. in the velocity of the wind at Samoa. In higher latitudes, while the wind frequently dies down at nightfall, and normally

weakens, windy nights are by no means uncommon, and very frequently the wind is stronger by night than by day. In the tropics, windy nights occur on lowlands only during the passage of rather rare severe cyclonic storms. Moreover, disturbances of an intensity which would give strong nocturnal winds in middle and high latitudes cause only moderate winds at night at low elevations in the tropics. This is due to the influence of the comparatively great decrease in vertical convection at night in low latitudes caused by the greater cooling of the surface air than of the overlying free air. It is for this reason also that even relatively steep barometric gradients in monsoonal regions permit a marked dying down of the surface winds at night.

(2.) Seasonal as well as diurnal variations in the velocity of the trades are common. "Half Gales" are characteristic of Fiji, the New Hebrides and many other South Pacific groups in their spring months, and even "whole gales" are frequent during the northeast "monsoons" in the China Sea during winter. On the other hand, in other months calms or light breezes are the rule when the doldrums migrate past, as they do twice each year with the seasonal change in the altitude of the sun. Along the margins of the tropics calms likewise occur when the extra-tropical belt of high pressure migrates equator-ward in the cooler season.

(3.) There is a radical seasonal change in the direction of the Trades when they cross the equator; those crossing from the north change from east-northeast winds to northwest, due to the deflective effects of the earth's rotation. Consequently many places near the equator have easterly winds much of the year; calms while the doldrums are migrating past, and westerly winds when the doldrums are situated in higher latitudes on their side of the equator. Then, as the sun returns equator-ward, calms and easterlies recur.

(4.) Another evidence of tropical variability is that land and sea breezes are more characteristic of the lower latitudes than of the higher. This is because the contrast in the temperature of land and water averages greater in low latitudes. Indeed while in middle and high latitudes sea breezes are rare except during the hottest weeks, in many parts of the lower latitudes they occur almost every day in the year, and give a wind régime which is very different from the constant easterly trades supposedly characteristic of the tropics. The monsoons are a special type of land and sea breezes, since they blow towards the land for many consecutive weeks during summer, and in the opposite direction in winter. While produced by temperature contrasts of extra-tropical regions, the monsoons are most strongly felt in tropical latitudes (below

30°) and give large and important regions a sharp seasonal contrast in wind directions. Between the winter and the summer monsoons, there commonly is a spell some weeks in length when the winds are irregular and often light. After they become steady in direction they often fluctuate notably in velocity from day to day as well as between day and night.

(5.) Although winds due to cyclonic disturbances do not occur so frequently within the tropics as in higher latitudes, they are significant. The "boxing of the compass," during which the wind comes from every direction in turn, occurs many times a year in most parts of the tropics, while occasionally cyclonic gales or even violent hurricanes occur. Official Japanese daily weather maps and annual summaries of storm tracks show an average of over fifty tropical cyclonic disturbances a year in east longitudes 115°-145°, while a study of the Australian daily weather maps for 20 years shows an average of over 30 a year in similar longitudes south of the equator. Thus in less than one seventh of the circumference of the earth there are over 80 cyclonic disturbances in an average year. This is, however, the stormiest sector.

Mention should be made of thunder squalls which are, on the average, more violent in low latitudes than in higher latitudes and more frequent. In addition, several regions in subtropical latitudes experience tornadoes or similar storms. Thus it is evident that there is considerable variation in respect to winds in the tropics.

Variations in rainfall have perhaps even greater significance than variations in temperature or wind. The indications are that in respect to dependability of precipitation, the lower latitudes are notably less fortunate than are middle latitudes. In order to compare the variability of rainfall in the tropical half of the globe with that of the higher latitudes, I have inspected the official records for many cities in both zones. The selection was impartial, being determined solely by whether or not the data were available. The comparison is between the greatest and least annual precipitation officially recorded before a recent year. The length of the record varies, but in general it is shorter in low than in higher latitudes and hence tends to lessen the apparent range in lower latitudes. Tables 3 and 4 give the figures to the nearest one tenth of an inch. It will be noticed that the maximum amount of rainfall received in a year was less than twice the minimum for Chicago, Christiania, Edinburgh, Ottawa, Paris, Pekin and Tokio, and only a trifle more than twice the minimum in the case of Amsterdam, Berlin, Berne, London, New York, Petrograd, St. Louis, Vienna and Wellington, N. Z. Very few middle or high latitude cities appear to have ex-

perienced three times as much precipitation in their wettest year as in their driest. Madrid, Washington, D. C., and Vladivostock are exceptions as are some cities in southern Europe, while Hobart, Tasmania, Buenos Aires, Rome and San Francisco are notable for having received about four times as much. However, many geographers class Buenos Aires, Rome and San Francisco as subtropical. Furthermore, Madrid and Vladivostock have an average rainfall of less than 20 inches, and thus are more subject to large percentage changes than is the case where the normal rainfall is larger.

TABLE 3

EXTREME ANNUAL RANGE IN RAINFALL IN MID-LATITUDES

City	Latitude	Average Rainfall	Driest Year	Wettest Year
Amsterdam	52° N.	27.3 in.	17.6 in.	40.6 in.
Berlin	52° N.	23.0	14.3	30.0
Berne	47° N.	36.3	24.7	58.2
Buenos Aires	35° S.	36.8	21.5	80.7
Chicago	42° N.	33.5	24.5	45.9
Christiania	60° N.	22.5	16.3	31.7
Edinburgh	56° N.	25.2	16.4	32.1
Hobart	43° S.	23.7	13.4	43.4
London	51° N.	24.0	18.2	38.2
Madrid	40° N.	16.2	9.1	27.5
New York	41° N.	42.5	28.8	59.7
Ottawa	45° N.	33.4	26.4	44.4
Paris	49° N.	21.9	16.4	29.6
Pekin	40° N.	24.4	18.0	36.0
Petrograd	60° N.	21.3	13.8	29.5
Rome	42° N.	32.6	12.7	57.9
San Francisco	38° N.	22.8	9.3	38.8
St. Louis	39° N.	37.4	23.4	49.2
Tokio	36° N.	59.2	45.7	77.1
Vladivostock	43° N.	19.5	9.4	33.6
Vienna	48° N.	24.5	16.5	33.9
Washington	39° N.	43.8	18.8	61.0
Wellington, N. Z.	42° S.	49.7	30.0	67.7

Turning now to the lower latitudes: Among 20 scattered cities selected impartially, in no case was the officially recorded rainfall of the wettest year less than twice that of the driest. Only in Calcutta and Caracas did the ratio fall as low as 2¼. In Johannesburg it was 2½ times as great, and in Durban, Hongkong and New Orleans it was 2¾. In Colombo and Honolulu it was about 3; in Bombay, Buenos Aires and Manila each about 3½; in Madras 4½; in Brisbane and Singapore 5; and in Rio de Janeiro 13.4. All these cities have a normal rainfall of 30 inches or over, and the mean for the group of cities is 55.6 inches in contrast with a mean of

30.5 inches for the cities of Table 3. Since percentage fluctuations tend to become smaller as the total rainfall increases, the great fluctuations experienced by these tropical cities are all the more notable.

TABLE 4

EXTREME ANNUAL RANGE IN RAINFALL IN LOW LATITUDES

City	Latitude	Average Rainfall	Driest Year	Wettest Year
Bombay	19° N.	71.1 in.	33.4 in.	114.9 in.
Brisbane	27° S.	45.6	16.2	88.3
Calcutta	22° N.	62.0	39.4	89.3
Caracas	11° N.	30.0	23.7	47.4
Colombo	7° N.	83.8	51.6	139.7
Durban	29° S.	40.8	27.2	71.3
Hongkong	22° N.	84.1	45.8	119.7
Honolulu	21° N.	31.3	14.6	45.0
Johannesburg	26° S.	31.6	21.7	50.0
Madras	13° N.	49.0	18.5	88.4
Manila	15° N.	76.3	35.7	117.0
Naples	41° N.	34.0	21.7	56.6
New Orleans	30° N.	55.7	31.1	85.7
Rio de Janeiro	23° S.	46.8	4.7	63.5
Singapore	1° N.	92.0	32.7	158.7

If tropical and subtropical cities having an average rainfall of less than 20 inches are included in the comparison, even more violent ranges are disclosed. For example, Cairo, Egypt and San Diego, Calif., each received about 6⅓ times as much rainfall in their wettest year as in their driest; Athens 7 times; Helwan, Egypt, 18 times; and Onslow, W. Australia, 47 times as great.

None of the cities of Table 4, except Singapore, happens to be close to the equator, the necessary data for other equatorial cities not being readily available. However, extreme fluctuations occur almost under the equator even on oceanic islands. At Malden Island (lat. 4° 1′ S.; long. 154° 58′ W.), for example, the annual totals of rainfall have varied from 3.95 inches in 1908 to 63.41 inches in 1905. At Oceanic Island (lat. 0° 52′ S.; long. 169° 35′ E.), nearly 2,000 miles west of Malden Island and within a degree of the equator, the range has been between 19.61 inches in 1909 and 158.93 in 1905 (141.12 in 1911). There was likewise a range of from 74 rainy days in 1910 to 232 in 1911. Upon the Hawaiian Islands, Puuhela, on Maui, (lat. 20¾° N.; long. 156½ W.) received only 2.46 inches of rain in 1912, but received 33.14 inches in 1918. Many other Hawaiian stations show a somewhat similar range, and the rainfall of the group as a whole is characterized by the government meteorologist as "extremely unreliable."

The great variability illustrated by these three mid-Pacific Islands is the more notable because insular climates are commonly

thought to be exceptionally uniform, particularly if near the equator and not dominated by near-by continental masses, nor within hurricane regions. None of these three is in a hurricane region, all are far from land and two are close to the equator.

So many other regions in low latitudes experience an undependable rainfall that it seems unnecessary to more than mention the famines produced by droughts in India and in southern China, or the destructive floods in the same countries. Tropical Australia has perhaps even worse droughts and floods and is saved from terrible famines only by the sparseness of the population and the skill used in reducing the losses to a minimum. The annual variation at Onslow in tropical West Australia, for instance, was from 0.57 inches in 1912 to 26.96 in 1900, and the average variability from year to year in that region has been about 50 per cent. of the average rainfall.

Excessive falls in short periods afford other illustrations of the uncertainty of rainfall. In tropical Australia, on more than 400 days in a 25-year period more than 10 inches of rain fell in 24 hours according to official records, while in temperate Australia there have been very few recorded instances of such heavy rainfalls—none in Victoria or South Australia and only two in Tasmania (Max. of 18.1 inches in three days). In tropical Australia, more than 20 inches has been officially recorded as falling in 24 hours on 42 different days, and more than 30 inches on four occasions. The maximum was 35.71 inches at Crohamhurst, Queensland, Feb. 2, 1893. However, 60 inches fell in three consecutive days at Mt. Molloy, Queensland, and there have been many 48-hour periods when more than 25 inches fell.

At Suva, Fiji, it frequently happens that more than 10 inches of rain falls within 24 hours; there were 4 cases in the 7-year period 1906-12. The maximum has been 26.5 inches in less than four hours on August 8, 1906.

What is believed to be the world's record for officially measured rainfall in 24 consecutive hours occurred near Manila on Feb. 14-15, 1911 (1,168 mm., 46 inches). The other stations at which this maximum has been approached are also in low latitudes, namely, Cherrapunji, India, June 14, 1876, 40.8 inches; Silver Hill, Jamaica, 57.5 inches in 48 hours; Funkiko, Formosa, 40.7 inches on Aug. 31, 1911, and at Hononu, Hawaii, 31.9 inches, Feb. 20, 1918.

With such sharp annual and daily extremes as these, it is reasonable to expect great monthly extremes. At Malden Island, mentioned above, for example, the range in officially recorded rainfall from 1890 to 1918 was as follows:

TABLE 5

MONTHLY VARIATION IN RAINFALL AT MALDEN ISLAND

January	from	0.00 in.	to	19.48	in.
February	from	0.00 in.	to	9.27	in.
March	from	0.15 in.	to	25.65	in.
April	from	0.47 in.	to	12.34	in.
May	from	0.29 in.	to	12.30	in.
June	from	0.00 in.	to	12.49	in.
July	from	0.59 in.	to	10.10	in.
August	from	0.18 in.	to	5.56	in.
September	from	0.05 in.	to	3.03	in.
October	from	0.00 in.	to	5.27	in.
November	from	0.00 in.	to	8.72	in.
December	from	0.00 in.	to	8.20	in.

The four months, November, 1891, to February, 1892, received a total of only 0.72 inches, while the four months, January to April, 1915, received over 60 inches. The number of rainy days per year varied from 30 to 144.

At Oceanic Island, likewise, the monthly ranges are extreme. Within a nine-year period, February, March, April and November have each received 0.1 inches or less and also 21.3 inches, 28.9, 27.6 and 15.5 inches, respectively, and falls of 0.7 inches or less in May, August, September, October and December are to be contrasted with falls of from 12 to 19 inches received in other years in those same months.

The Philippines show scarcely less violent extremes. In the 16-year period, 1903-18, 42 of the 70 stations had a total of about 160 months with no rainfall, while the wettest months at about half the stations exceeded 40 inches of rain, and had less than 20 inches in the case of only 8 stations. This variation is only partly seasonal, for a month which is very dry one year may be excessively wet another. Severe and widespread droughts, with over 100 days without rain, are contrasted with destructive floods caused by rainfalls of more than 20 inches in a day or two.

Even at Hilo, on the wet side of Hawaii, where the rainfall averages 139.4 inches a year and is relatively dependable, a 13-year period shows that the monthly amounts have varied widely, January from 0.5 inches to 38.6, February from 1.9 to 32.5 inches, March 2.9 to 45.4, April 3.7 to 25.1, and December from 1.7 to 27.8 inches, for example.

That the great variation from year to year in rainfall discussed in the foregoing pages is not local is suggested by various data. For example, the average rainfall of the entire Hawaiian group (150 stations) was more than twice as great in 1919 as in 1918 (112.9 in. vs. 54.5 in.). Likewise in the Philippines during the droughts such as that referred to in a preceding paragraph, nearly all of the 70 stations are affected similarly.

Another type of variation in rainfall which is prominent in the tropics is the seasonal. Very few tropical localities receive their rainfall as evenly distributed throughout the year as is common in many parts of middle latitudes. Distinct wet and dry seasons are the rule. The rainy summers and dry winters of India and China are well known. Most of tropical Australia also receives almost no rain for six months and from 15 to 50 inches or more in the other six months. Hawaii and many other places near the margins of the tropics receive much of their rainfall in winter, while still other parts of the tropics have two wet and two dry seasons.

In order to compare the monthly variability of rainfall in low and middle latitudes, a planimeter measurement was made of Supan's map of Percentage Range of Mean Monthly Rainfall in Bartholomew's Atlas of Meteorology. This map shows four types of regions: (1) where the wettest month is less than 10 per cent. rainier than the driest month; (2) where the wettest month is from 10-20 per cent. rainier than the driest; (3) where the range is from 20-30 per cent; and (4) where it is over 30 per cent. Tables 6 and 7 show the approximate area and the percentage of each type by continents. Table 6 concerns middle latitudes (30° to 60°); Table 7 concerns low latitudes (30° N. to 30° S.).

TABLE 6

PERCENTAGE RANGE OF MEAN MONTHLY RAINFALL, LATITUDES 30° TO 60°

	Range less than 10 per cent.		Range 10-20 per cent.		Range 20-30 per cent.		Range over 30 per cent.	
	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%
Europe	1.77	65	.88	34	.03	1	0	0
North America	2.06	43	2.62	54	.14	3	0	0
South America	.23	26	.55	60	.13	14	0	0
Asia	.22	3	2.65	34	3.75	49	1.13	14
Africa	.05	15	.23	44	.47	41	0	0
Australia	.36	47	.40	53	.005	.6	0	0
Total and Means	4.70	26	7.34	42	4.42	25	1.13	7

TABLE 7

PERCENTAGE RANGE OF MEAN MONTHLY RAINFALL, LATITUDES 30° N. TO 30° S.

	Range less than 10 per cent.		Range 10-20 per cent.		Range 20-30 per cent.		Range over 30 per cent.	
	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mil.	%	Mil. Sq. Mi.	%
North America	0	0	.46	39	.70	61	0	0
South America	.12	2	4.91	76	1.31	21	.04	1
Asia	.10	2	.96	23	2.56	60	.63	15
Africa	0	0	2.28	20	8.86	78	.21	2
Australia	.16	7	.63	28	1.32	59	.13	6
East Indies	.43	36	.72	63	.01	1	0	0
Total and Means	.81	3	9.76	38	14.76	55	1.01	4

It will be seen that low latitudes have over three times as large an area possessing a monthly variability of over 20 per cent. as is the case in mid-latitudes and twice as large a percentage of their total area has this range. The one large area in mid-latitudes having the fourth, the most extreme, type of rainfall variability is the Tibetan Plateau, which has little agricultural value because of its great altitude. Furthermore, the month of least precipitation in mid-latitudes commonly is in the winter when plants require little moisture while the wettest month usually is in summer. On the other hand, the driest month of the tropics is also a hot month, with active evaporation. This unfortunate combination is very hard on plants, and is the reason for the lack of forests in many places having a large annual rainfall. For instance, parts of tropical Australia having over 60 inches of rain a year possess no real forest because several months are extremely dry and hot.

In respect to the more uniform rainfall type, where the range between the driest and wettest month is less than ten per cent. mid-latitudes have nearly six times as large an area as low latitudes. This type comprises about 26 per cent. of the total land area of mid-laditudes while it makes up only 3 per cent. of low latitudes. Other interesting comparisons come out on further study of these tables.

Why should the lack of marked seasons in respect to temperature be emphasized and the presence of marked seasons of rainfall be largely ignored by most writers on the tropics?

Another climatic factor subject to marked changes is storminess. Cyclonic storms are erratic in all parts of the world but the extremes appear to be greatest in low latitudes. The range in the number of hurricanes damaging Australia, for example, has been from one hurricane in 1907 and 1919 to seven in 1916 and eleven in 1912. In Fiji some years have none, but several years have had three each and one year four. In the South Indian Ocean the variation reported by the Mauritius Observatory has been from one storm in 1900 to eight in 1894 (and several other years) and to thirteen in 1913. In the Philippines in a 15-year period the number of very severe typhoons varied from one in 1916 to seven each in 1908 and 1911. In respect to less violent cyclonic storms there appears to be a somewhat similar range. For example, the total number of well-marked tropical cyclones occurring in Queensland, Australia, varied from eight in 1920 to 24 in 1916. In respect to the month of occurrence, as well as in annual frequency, there likewise is marked irregularity. In some years cyclones may be lacking during the months when they normally are most frequent and occur only in months supposed to be

free from dangerous storms. Of thunder storms also there is marked variation, perhaps more than in higher latitudes. Many stations in Fiji and elsewhere have experienced several times as many in one year as in another. While many hurricanes are accompanied by appalling lightning, other equally severe hurricanes have none.

Slight changes of weather are almost constantly taking place in the tropics. A rainy spell will be succeeded by a less rainy one or by a few rainless days; a hot spell by a slightly cooler one; a spell of fitful breezes, by several days of steady winds. Such changes have been noticed by the writer in Jamaica, Hawaii, the Philippines, the East Indies, Queensland and elsewhere, but have been especially studied in Fiji. There, a study of the official records taken at Suva reveals an average of about 20 distinct spells of weather well distributed throughout the year, with about as many less distinct changes.

In conclusion, when all these types of variation occur, is it right to give the impression that tropical climates are extremely uniform? But although tropical climates are not so uniform as has been supposed, it does not follow that they are better adapted to civilized man than has been supposed. Most of the variability within the tropics is of a highly irregular sort compared with the variability characteristic of the parts of the higher latitudes where civilized man mostly lives. Indeed it appears that tropical climates are unfavorable for a high type of civilization not alone because of the high temperatures and the general lack of stimulating seasonal changes in temperatures, but also because of the often extreme undependability of the rainfall, the occurrence not infrequently of destructive windstorms and other unfavorable variations. But, nevertheless, highly civilized man can cope with the numerous problems of the tropics far better than can primitive people. Indeed, the latter, unaided, have made little progress. Hence fuller utilization of the tropical resources awaits a greater participation by civilized man.

THE POSSIBILITIES OF EXTERMINATING INSECTS

By Dr. E. P. FELT
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THIS is a special phase of the war against insects, the general aspects of which have been discussed in such an illuminating and very suggestive manner by Dr. L. O. Howard, chief of the Federal Bureau of Entomology, in his address as retiring president of the American Association for the Advancement of Science.[1] Dr. Howard has given in this account a most excellent summary of the broader phases of insect control, though, for some reason, possibly because he knew of the writer's interest therein, he refrained from discussing exterminative measures or the possibilities of eradicating isolated infestations.

This is something of considerable practical importance on account of the fact that more than half of our most injurious insect pests have been introduced from abroad and the process is still going on in spite of the widespread and, as a whole, well directed Horticultural Inspection Service of the general government and the various states. This latter work has undoubtedly prevented the establishment of a number of injurious insects and delayed the introduction of others, though occasionally we find a destructive pest well established in a section and in the ordinary course of events destined to extend its range and possibly inflict very serious losses over a considerable period of years.

The Gipsy Moth, the Brown-Tail Moth, the Elm Leaf Beetle, the Leopard Moth and the recently introduced Japanese Beetle are somewhat familiar examples in the eastern United States, while the south has become altogether too familiar with the Boll Weevil, the Pink Boll Worm and very lately the Mexican Bean Beetle. There is, in addition, the recently introduced European Corn Borer, now beyond any possibility of extermination so far as this hemisphere is concerned, though at one time it must have been within possibilities. We are also confronted in the early history of the Gipsy Moth with the futile attempt of the state of Massachusetts to exterminate the insect, while later developments dem-

[1] (*a*) "On Some Presidential Addresses"; (*b*) "The War against Insects." *Science*, 54: 641-651, 1921.

onstrated beyond question the practicability of accomplishing what at one time appeared to many as an unattainable ideal.

It must be conceded at the outset that problems of this nature are surrounded by manifold difficulties and that, within certain limits, each case must be decided upon its merits. In the first place, it is exceedingly difficult to determine the future status of an insect before it has become well established and thus presumably ineradicable, unless some unusual limitation makes extermination relatively easy. Granting that there is substantial agreement among scientific men as to the desirability of exterminating a given species, the great problem of educating the public to view the matter from the right standpoint and thus make possible the securing of means to prosecute a vigorous campaign still remains to be solved. Furthermore, initial operations, if the undertaking is to be successful and conducted in the most economical manner, must ordinarily be started before successful measures have been thoroughly demonstrated. There is always an element of doubt in regard to the possibility of serious injury, the feasibility of extermination and the methods to be employed, consequently it is not easy to secure a combination which will bring about the desired results. On the other hand, there is practical agreement among most scientific men familiar with the work of insects to the effect that extermination, when possible, is immensely cheaper and more desirable than the prosecution of more or less unsatisfactory control measures in a constantly expanding infested territory.

Earlier attempts to exterminate insects were based largely on some plan designed to catch or kill the last remaining insect, preferably within a year or two and certainly within a few years. Some have even advocated reducing the infested territory to practically desert conditions in such a manner as to make all insect life at least impossible. This latter is undoubtedly possible in the case of very restricted infestations and may be justified if the insect is an exceedingly destructive or dangerous one. It is out of the question if an extended area is infested or the insect one which is not particularly dangerous to life and does not threaten a basic crop or industry. Most cases come in this latter category and therefore do not justify extreme or drastic measures.

It seems to the writer that the method of progressive reduction, if one may use a special term, has not received the consideration it deserves, and yet it has been the method which has brought about extermination of Gipsy Moth colonies in areas well removed from the generally infested territory. The plan in such a case was to bring about conditions unfavorable for the multiplication of the insect and, by following up the matter from year to year,

eventually reduce the numbers of the pest so greatly that natural agents or hazards actually bring about extermination. It is interesting in this connection to review the work of the earlier days against the Gipsy Moth when a systematic and very costly effort was made to find every egg mass in woodlands as well as on improved grounds and destroy them by hand, trees being climbed and walls taken down and relaid in the search for the last egg mass. This was supplemented by spraying the foliage in the infested area and banding the trees for caterpillars. Later developments have shown that much of this laborious egg hunting can be eliminated by a system of spraying and cutting out low bushes or favored food plants. Conditions are thus changed to such an extent that the insect is unable to maintain itself and eventually disappears.

Apparently, because insects are small and under certain conditions exceedingly abundant, we have failed to make allowance for the results following a great reduction in the number of individuals, especially if this be continued year after year. The matter is of more than passing importance, because there is a possibility of making practical application of the principles involved and obtaining at a relatively moderate cost results which might eventuate in large savings by eradicating injurious species before they had an opportunity of establishing themselves over extended areas.

It may be held that the Gipsy Moth is in a class by itself and to a certain extent this is true. Nevertheless, until this method has been widely tested with a variety of insects, no one is in a position to state that it is impracticable. Even a casual study of injurious insects shows marked local variations in abundance. These must be due to some cause, and in many instances they are directly associated with agricultural practices or differences in natural conditions. The detection of such unfavorable conditions and the bringing about of similar modifications in areas where insects are destructive, is one of the opportunities of the economic entomologist and, as stated above, there is a probability of the same principle being applied successfully to the extermination of recently introduced injurious insects, provided the infested area is not too large. This last is not necessarily an insuperable difficulty. It may simply mean a better organization and an extension of operations over a longer period of time.

If we turn from the field of entomology to the broader realm of zoology, and consider what has occurred in the case of larger forms, we may find some very suggestive hints. It should be noted in this connection that in not a few instances the apparently impossible has been brought about by the irresponsible urge of self interest and not through carefully directed cooperative efforts for the attainment of a definite aim.

One of the most striking instances of this kind is the extermination of the Passenger Pigeon, a bird at one time so extremely abundant that three carloads a day were shipped from one small Michigan town for a period of forty days. The Great Auk, the Labrador Duck and the Pallas Cormorant have passed into history. The Whooping Crane, the Trumpeter Swan, the American Flamingo, the Heath Hen and Sage Grouse are representative of a series of valuable and interesting birds doomed, in the opinion of Dr. Hornaday, to early extermination.

Large herds of Buffalo were saved from extinction at the last moment through the intervention of naturalists interested in preserving the wild life of the country. The Prong-Horned Antelope, the Big-Horn Sheep, the Mountain Goat and the Elks are traveling the same path as the Buffalo.

The depleted salmon, shad and herring fisheries, the necessity of protecting both the oyster and the lobster and the great scarcity of certain whales have been brought about by artificial agencies, though it would seem as if inhabitants of the water would have a better chance for escape from a persistent human enemy than would be the case with terrestrial forms.

It is true that these unfortunate conditions have resulted through specific peculiarities or limitations which made attack at certain points particularly effective, such as killing birds when migrating or in their nesting retreats or the wholesale catching of spawning salmon. Those dependent in large measure for their living upon some of these forms could not believe that the natural prolificacy of the species would not offset almost any levy by human or other agents. Are we not unconsciously assuming that because insects are apparently innumerable, systematic general measures continued over a series of years are foredoomed to failure? It by no means follows that immense numbers indicate impossibility of control or extermination.

The stimulus of a deadly peril is sometimes necessary to demonstrate the practicable. This has occurred in the case of yellow fever and, while the insect carrier was not exterminated, it was soon found entirely possible to greatly reduce the breeding of the "day mosquito" and by a combination of mosquito control measures and preventing insects from gaining access to infection, the disease was actually eradicated. The deadly peril of plague on the Pacific Slope drove home the lesson that safety lay in rat eradication and that this latter could be accomplished only by a simultaneous attack upon the rat, its food supply and habitations. This was carried to the extent of exterminating rats over considerable city areas. Given adequate incentive, there appears to be no prac-

tical reason why rat extermination could not be extended to entire cities or smaller communities through systematic repressive measures extending over a series of years. In this connection, it may be permissible to allude to the so-called Rodier method of rabbit and rat control, which depends simply upon systematic trapping and destruction of the females and the liberation of the males, since an excess of the latter, it is claimed, results in extermination or near extermination due to persistent persecution by the males of the constantly decreasing number of females. It is based on the utilization of well-known habits to bring about self destruction of the species.

The studies of bark beetles by Dr. Hopkins have shown the possibility of securing very efficient control by simply reducing their numbers, in some instances by 75 per cent., to such an extent that those remaining would be unable to overcome the natural resistance of the tree. This applies to enemies of living trees and presupposes that a minimum amount of injury must be inflicted or the attack can be successfully resisted. Were there sufficient incentive, it might be possible to go further with certain of these insects and bring about local extermination.

A concrete application along these lines is found in the attempt of recent years by the United States Biological Survey to destroy predatory animals such as wolves and coyotes and thus eliminate in large measure the very heavy losses of western stock growers. The work is organized on a cooperative basis with states and local associations and as a consequence losses have been practically ended over great areas of the most valuable summer and winter sheep ranges and reduced in others to very small amounts compared with earlier years. The practical value of such work is evidenced by the fact that interested states, in order to cooperate with the government, appropriated over $200,000.00 for the fiscal year of 1922, in addition to increased contributions by stockmen as individuals and through their organizations. Already areas have been cleared or partly cleared of the pests and it would seem from the progress made entirely possible to exterminate the most destructive of these animals throughout the more important stock-raising areas at least, and this through the well directed efforts of a relatively small number of individuals.

The systematic destruction of prairie dogs has resulted in over four million acres of public lands being "largely freed" from these pests. There has also been very effective work against pocket gophers and rabbits. It is within possibilities to make local and almost complete eradication absolute and thus in the course of years free large areas from serious pests.

The work of W. F. Fiske upon the Tsetse Fly has shown that it is only necessary to reduce the infestation by this pest to moderate limits in order to secure a very satisfactory degree of freedom from the deadly sleeping sickness. The studies of Roubaud upon malaria in France indicate an intimate connection between this infection and the number of mosquitoes per host. The author suggests what he calls animal prophylaxis, that is, the importation of enough cattle in certain areas to attract the insects and thus protect man to a large extent. The keeping of rabbits has been advocated more recently as a protection from malaria, and may be regarded as a variant of Roubaud's plan. All are forms of percentage reduction, a step which under certain conditions might be continued to the vanishing point, at least, so far as the infection is concerned.

Turning to the Acarina, we note the progressive extermination of the Cattle Tick from nearly 500,000 square miles of territory, and the consequent elimination from this area of a very serious infection. It was apparently an impossible undertaking until the decisive factors were ascertained. In this connection, it might be stated that gratifying progress has been made in demonstrating methods of controlling the Rocky Mountain spotted fever tick, a carrier of a deadly human infection. Even now plans are in progress to test the possibility of actually exterminating warble flies from large areas. This is somewhat different from the tick proposition. It appears to be within possibilities and is certainly worth a thorough test.

The history of the larger animals shows a number of cases of extermination or near extermination as a result of continued adverse conditions, and in historic times this has been due mostly to systematic hunting or fishing, and usually it has been confined to a restricted portion of the range, though in some instances it occurred at a period which would permit the maximum reduction in the species, namely, just before the breeding season.

The mere fact that a species occurs in immense numbers does not make extermination impossible, though it may greatly prolong the period during which adverse influences must operate.

It is evident from a study of insects and an examination of the factors resulting in the extermination of larger animals, that relatively minor changes in environment or well organized attacks limited to relatively few individuals or to comparatively restricted areas, may accomplish the apparently impossible.

It is also evident that the elimination of a certain residuum may safely be left to the operation of various natural causes. This latter is an extremely important factor in any attempt to exterminate

insects, since it is usually impossible to destroy the last individual or to bring about conditions over an infested area of some extent which would make the existence of insect life impossible.

In view of the above, we believe that the problem of insect extermination should receive most careful consideration and as opportunity offers, tests or demonstrations should be undertaken in order to obtain more trustworthy data relative to possibilities in this line of repressive work.

CITY PARKS AND PLAYGROUNDS AS HEALTH AGENTS

By Dr. JAMES M. ANDERS
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THE necessity for providing sufficient city parks and play spaces, including parkways and garden-streets, has been long appreciated by students of municipal sanitation and the truly enlightened part of the general public. We owe the existence of organized bodies for the purpose of promoting these agencies, all of which have been founded within the last half century, to a few leaders in the matter of community health and welfare and in civic advancement. As the result of their well-directed efforts considerable progress has been made in the important direction of providing an adequate proportion of open spaces in relation to the density and aggregate of municipal populations. Efforts to arouse public sentiment upon this vitally important question, however, should have received far greater encouragement than they did in the past.

In this connection it should be recollected that in consequence of the free immigration of inferior races our national physique has shown up to now a slow and gradual retrogression. It is high time that an intelligent, concerted effort be made with the avowed purpose of arresting this physical decadence and, more than this, of beginning a new advance. To the student of hygienic and sanitary principles the sources of bodily and moral efficiency are not obscure, and with the aid of sufficient popular support he can indicate the remedies for the cure of the existing state of things with reference to our physical deficiencies.

It will not prove difficult to show the connection of city parks and playgrounds with racial progress due to improvement in the national physique. Indeed, it is not too much to claim that a just appreciation of the beneficial effects of these breathing and play spaces of our cities would speedily lead to the acquisition of new areas and the development of land owned by cities for park and play purposes; this would mean a distinct advance in city building with reference to such questions as the number of houses to the acre, their proper grouping, and the extent of open spaces between units, as well as in street tree planting, all of which questions

affect the health and strength of the community, as will be clear hereafter.

The thirtieth annual report of the City Parks Association of Philadelphia sets forth the rôle played by the United States Government in physical demonstration of town planning on a large scale carried into execution in several localities, notably Yorkship, Portsmouth, N. H., and Wilmington, Del., during the recent war. Here was established a standard for city planning that it would have required a much longer period of time—quite a generation at least—to attain to in peace times. Attention should be directed to such government regulations as building ten to twenty feet back of the street line, fewer houses to the block and open space between adjoining houses, sixteen feet being the minimum. It is to be hoped that this example set by the government will not be lost, but will serve to inaugurate an era of decided progress in city building throughout our broad land. It is the duty of public-spirited citizens to see to it that modern town plans be adopted in connection with the future building of towns or settlements. True it is that out of appropriate town planning, as necessary sequences, grow hygienic and moral conditions which possess far-reaching influences for good. In other words, if our great American cities were models of city planning the effect would be not only greatly to increase real estate values, but also and more importantly to advance the essentials of human health and happiness. Confirmation of this statement is to be found in an article by Andrew Wright Crawford on "War Suburbs and War Cities," in which he quotes from a book by Charles Cadbury, Jr., the figures appended; they show the effect on children of the Garden Suburbs of Bournville, England, as compared with a ward in Birmingham, only twenty minutes away:

WEIGHT	Lbs. years, Age 6	Lbs. years, Age 8	Lbs. years, Age 10	Lbs. years, Age 12
Boys, Bournville	45.0	52.9	61.6	71.8
Boys, St. Bartholomew's Ward, Birmingham	39.0	47.8	56.1	63.2
Girls, Bournville	43.5	50.3	62.1	74.7
Girls, St. Bartholomew's Ward	39.4	45.6	53.9	65.7
HEIGHT	Inches	Inches	Inches	Inches
Boys, Bournville	44.1	48.3	51.9	54.8
Boys, St. Bartholomew's Ward	41.9	46.2	49.6	52.3
Girls, Bournville	44.2	48.6	52.1	56.0
Girls, St. Bartholomew's Ward	41.7	44.8	48.1	53.1

An important project of city planning is that of zoning, which "expresses," to quote Herbert S. Swan in the *American Architect*, "the idea of orderliness in community development." The zone plan tends to strengthen and stabilize real estate values, in short

to bring about improvement in real estate conditions and, more important still, encourages efforts to beautify private home sections by street tree planting and the creation of garden streets. Unquestionably, the excellent suggestion contained in a Bulletin of the American Civic Association to the effect that iron fences be substituted for board back fences and board side fences should be adopted. The use of wire and iron for such fencing would not obstruct air-currents as do board fences; and the former "invite flowers and backyard gardens" and "spur competition in cleanliness, neatness and attractiveness." No city should be content without a comprehensive scheme or program for its orderly development to which no single factor would contribute more in the way of beauty and physical benefit than a proper park system including adequate playgrounds.

Trees, as all know, appeal strongly to man's esthetic taste, and this is even more true of an aggregation of trees, shrubbery and flowers, such as may be seen in public squares and city parks. The fact that these vegetable forms exercise certain moral effects, especially a softening and refining influence upon human mind and character, is not open to dispute, but it is scarcely appreciated to the extent that it so richly deserves. City parks adorned with trees, foliage plants and blooming vegetation tend to delight the mind, to divert the attention and relieve ennui. Who has not felt keen pleasure at witnessing the gorgeous beauty of a Rittenhouse Square, or a Campanile in spring-time, or failed to experience the benefit they confer in ministering to his or her esthetic taste and gratifying the senses? Here it should be insisted that there is every reason why we should have displayed in our city parks true art, which should be, however, based on the delicate realities or really beautiful things of nature, with a minimum of human imagination and invention. There is opportunity in this connection for the artist who makes a clear-eyed study of the divinely settled trees, shrubs and flowers which enter into the making of our city squares in their true form.

While parks serve as a place of rest and relaxation, the presence of trees and flowering plants gives a feeling of companionship often tending to brighten and cheer the lonely hours of many who have little opportunity to enjoy life. The writer fully concurs in the view so happily expressed by the London *Medical Record*, namely, that "growing plants and flowers is valuable *delassement* for the weak and weary."

The principal object of this article, however, is to show the value of city parks, open spaces, playgrounds and the like as sources of health and strength, if rightly used. The view is generally held

that a high average physique is the most valuable asset that a municipality, state or nation can boast. Health means freedom from illness, but more than this it means the possession of a reserve force necessary to meet the emergencies of life. The recent war has shown that the American race is distinctly inferior from a physical viewpoint, the percentage of those defective in body among the young men who applied for service being as high as 39 per cent.

Experts who have made an investigation into the causes of physical disabilities of our adult population are in agreement that the principal factors are immigration of inferior races and malnutrition, the result of unsanitary conditions under which they live. Improper and inadequate food plays a leading rôle, but it is no more potent as a disabling agency than lack of pure air and sunshine due to congestion. To overcome in a measure at least the evils of overcrowding which prevails so generally in our large municipalities, a sufficient number of open squares—not less than one eighth of the total surface area, appropriately located, is to be advised and encouraged. A proper park system, such as has been projected in Kansas City, Minneapolis and elsewhere in this country should be looked upon as a conspicuous part of the sanitary arrangements of any municipality. It is obvious that a majority of our cities, especially the older ones, are greatly in need of new open spaces in order that their sanitary requirements shall be met.

There are a number of ways in which these breathing spaces or city parks with their foliage and flowers, in right proportion to the population and properly distributed, increase the healthfulness of the citizenry, apart from their esthetic influence and their happy effect in relieving congestion. In the first place they render hygienic service by producing shade, which has a cooling effect, and, moreover, sets the air in motion, giving rise to gentle currents. But the full sanitary significance of city parks, garden streets and parkways is not appreciable without a consideration of two plant functions; they are, first, transpiration, by which is meant the constant evaporation of watery vapor which takes place from their leaf surfaces, and, secondly, the power possessed by scented foliage, *e. g., pine leaves,* and all flowering vegetation (as shown by the writer's experiments)[1] to convert the oxygen of the air into ozone, the natural purifying agent of the atmosphere through its oxidizing properties. That growing vegetation gives off oxygen to the surrounding air in an amount sufficient to improve the quality of this medium for breathing purposes is a fact of much sanitary significance, and one that rests upon reliable experimental evidence.

[1] "House-Plants as Sanitary Agents; Relation of Growing Vegetation to Health and Disease," pp. 133-136.

On account of their function of transpiration trees and plants generally, more particularly those having soft, thin foliage, tend to increase somewhat, and to maintain, a state of equability in the degree of the atmospheric humidity in their immediate vicinity. It is high time to abandon the view formerly dominant that an antagonism due to certain plant functions exists between the animal and vegetable kingdoms. There is a deeply rooted belief that plant respiration impairs the salubrity of the surrounding atmosphere. The results of the experiments by Pettenkofer, however, indicate conclusively that the amount of oxygen absorbed from the air and the percentage of carbon dioxide exhaled as the result of plant breathing are too small to exert any appreciable effect. It can be shown that plants, even blooming plants in a sleeping room, so far from exerting an unhealthy influence, are all the while making the air in a better condition for human lungs by diffusing moisture and generating ozone, not to speak of the affinity resulting from association with these living objects. Parks serve as a ventilating apparatus for cities, introducing, as they do, a greater abundance of purified air than is otherwise possible. Indeed the effect upon the public health and character of an adequate park system is altogether noteworthy.

Among suggested memorials to the soldier dead, nothing surpasses either in point of fitness or durability a city park or a parkway filled with its trees of remembrance. City parks if rightly kept would be flourishing monuments of living, lasting green for this and coming generations. Says the Rochester *Democrat and Chronicle* in this connection, "Not only would such a memorial be a thing of beauty and a joy for many generations by keeping fresh the memories of heroes of the world's great crisis, but it would be a source of comfort in the heart of summer to countless thousands; perhaps, it would save the lives of many in the course of its existence."

It is to be hoped that the project of planting trees along our streets and public highways generally will be vigorously furthered. To quote from *American Forestry*: "By all means let us have trees of remembrance. Let us have them abundantly and for every possible memorial. They are the true monuments, the living memorials God has provided to hallow the holiest memories of every person and of every race."

Another source of national health, strength and happiness from the standpoint taken by the hygienist as well as the political economist is children's playgrounds. Experts concur in the view that childhood is the time to begin to build up the physical reserve of a nation, which is to play so important a rôle in personal enter-

prise and success later in life as well as in municipal progress. It is during the period of public school life that the body is most in need of the strengthening and invigorating effect of suitable muscular activity. Recent investigations in a large number of schools have shown that twenty-five out of twenty-eight children are physically defective. A definite health program therefore should be made a conspicuous part of every public school curriculum, and the acquisition of health among children demands ample provision for play in the open.

Recreation is of value not only in preserving the health of individuals, but also in the treatment of physical and mental ailments. The effects of the garden city movement in Great Britain, already given in tabular form, will serve to emphasize the value to a race or nation of ample opportunity for our growing girls and boys to play out of doors. Moreover, regular and well-supervised recreation exercises are potent preventives of the great white plague and other chronic diseases. Said the International Congress on Tuberculosis recently, "Playgrounds constitute one of the most effective methods for the prevention of tuberculosis and should be put to the fore in the world-wide propaganda for the diminution of its unnecessary destruction of human life." One of the objects of playgrounds is to make them centers of hygienic instruction and to teach proper habits of living and create a love of wholesome outdoor games and sports, with a view to habitually stimulating the normal physiological processes of the body.

Obviously the largest measure of success in carrying out this health-giving measure is to be attained by a study of the needs of the individual. It is not too much to claim that sufficient play, properly supervised, would successfully overcome a large percentage of the physical defects of childhood. Obviously playgrounds must be supplied with suitable apparatus (which is not always the case), if good results are to be expected.

Here mention should be made of the fact that thoroughfares are being set aside as "play streets" in many of our large municipalities. These are to be advised and encouraged as part of a scheme for the physical development of children, but do not compare with especially built recreation or play centers as means to strengthen the nation's youth. The need of more attractive, supervised play spaces with proper equipment is only emphasized by making the most of inherent existing possibilities, as shown by the utilization of our thoroughfares as "play streets."

There would seem to be immediate urgency in the matter of a careful survey of our leading cities with reference to this question of playgrounds. It is well known that Chicago and Philadelphia

lead with respect to the number of children's playgrounds, but up to now we have not this aid to a full appreciation of the status of the subject in an immense majority of American cities. The playground problem is easily one of the most vital questions of our municipal governments to-day, and while the demand of these sources of strength and national reserve outstrip the financial resources in most cases at least, it is time that our best efforts be directed toward the solution of the problem.

It is a present-day axiom that all must work and play; hence playgrounds should also be provided for those of mature age. Says Dr. Hall aptly, "We do not stop play because we grow old, but we grow old because we stop play." We may not agree with those modern experts who contend that out of every twenty-four hours eight are to be devoted to work, eight to sleep and eight to play, but it is a recognized fact that plenty of daily play or recreation exercise is indispensably necessary to avert staleness, inefficiency and even illness. It is not denied that play can take various forms with good effect, as will be pointed out presently. After play we re-enter the fray serene, clear-eyed and confirmed.

The fundamental principle to be borne in mind in the application of recreation exercise or play in the mature adult is that the needs in this respect differ in different classes of individuals. For example, the mental worker requires diversion for the mind into other than the usual channels, but he requires above all else systematic daily muscular activity while at play. *Per contra*, those engaged in manual, laborious pursuits may get sufficient muscular exercise; they are, however, in need of mental relaxation and recreation.

During the late war Uncle Sam was actively engaged in planning playgrounds for the soldier boys during their hours of relaxation. The armistice came, and these playgrounds were not created. The need of a place and opportunity to play, not only for soldier boys, but for the entire mature population is quite as important during peace times as during war times. There is no reason why adults should not utilize the school recreation centers and children's playgrounds at certain periods of time, but they must not be allowed to crowd out the young. The social and industrial life of an urban community would be vastly improved by the building of an adequate number of playgrounds for the use of parents and of older brothers and sisters of our school children, in short for the whole adult population. While play for children of school and pre-school age is an important factor in the making of future generations of men and women, it would be profitable indeed for the general public to maintain its interest in, and im-

prove every opportunity to dedicate itself seriously to, healthful forms of recreation in the open, such as can be arranged for in appropriate open play spaces.

A campaign for the purpose of arousing public sentiment for the better protection of our national parks would be timely, since these with their natural scenic and historic features should at all hazards be preserved as great and unique public playgrounds. Unquestionably, they should be withdrawn from commercial and industrial developments, which have been permitted in recent times. It is to be hoped that the government will formulate a definite policy that would be in conformity with an effective, broad program calculated to gratify every friend of the national park system and thus protect our actual and vital public interests. The country stands in need of the development of more abundant recreation opportunities.

FINNISH POETRY—NATURE'S MIRROR

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OUT of the mêlée of the world's masses of struggling humanity striving during the past eight years to attain "a place in the sun," there has been born a new republic—the Republic of Finland. The birth of this republic was the signal for a glorious Finnish celebration, for it marked the termination of century-old efforts to throw off the yoke of a Russian autocracy. The Finnish declaration of independence attracted the entire world. The great powers affixed their stamp of approval and turned to other world affairs perhaps of greater significance. However, for the Finn the event was notable. He may now and for generations to come, with justifiable pride, tell to his children the story of the "Declaration of Independence" of December 6, 1917, and of the Constitutional law of June 14, 1919, whereby Finland officially declared herself a member of the world family of republics.

The Finns are a unique people. The development of their nationalistic spirit is likewise unique. This spirit was crystallized by the conversion of their folk-song into a national epic—the Kalevala, an epic ranking in quality and originality with the Iliad, the Odyssey and the Niebelunge. The Finns are an imaginative folk, a characteristic they owe to their oriental ancestry. There is little doubt that the first settlers in Finland migrated from central Asia, probably from the region of the Altai mountains. They brought with them a high regard for the controlling influences of the laws of nature and an unequalled devotion to the out-of-doors. They deify the elements of nature, and list among their gods, the God of Waters, God of Forests, God of Fire, God of Breezes and numerous others. Their mythology is essentially a nature worship. In the Kalevala it finds its best expression.

For the composition of the folk-songs into epic form, the Finns are indebted to Elias Lönnrot, first a physician and later a professor of the Finnish language. He appreciated the beauty, the charm and the rare culture expressed by the Finnish folk-songs and resolved that they should be preserved to posterity. These verses, sung through the ages, had never been recorded, so Lönnrot determined to collect them. He traveled to the remotest parts of

Finland where modernisms had not yet penetrated and as he listened hour after hour to the singing of the peasantry, faithfully recorded each canto. Most of the songs were collected in the remote northern portions of the province of East Karelia. Returning home with his note-books bulging with invaluable records, Lönnrot knitted the verses into a homogeneous whole of some 27,000 lines, and in 1835 gave to the world the results of his years of untiring efforts—the Kalevala.

The Kalevala brought home to the Finns the realization of a common language. For the first time did they appreciate the possession of a language meriting the same consideration as Russian, German, Swedish or other recognized national tongues. They further saw the basis for a sympathetic bond among all the Finns and so, almost as soon as Lönnrot's magnificent work made its appearance, it was hailed as the epic of the Finnish people. The Kalevala marked the virtual beginning of an intensive spirit of nationalism throughout Finland.

While all writers do not credit the Kalevala as a true epic, nor wholly discredit it as such, nevertheless they regard the production as extraordinary and certainly approaching closely to an epic. In any event, be it an epic or nearly so, there is agreement as to the uniqueness in its style, in the beauty of its conceptions and in its dramatic presentation of the struggle for existence among a people never known to flinch under the stress of nature's most discouraging environment.

Before detailing the content of the Kalevala, it is of interest to note the peasant's manner of singing the runes. The singers seat themselves upon low benches or stools, and facing each other with outstretched arms, take hold hands; then, as they sway their bodies to and fro in see-saw fashion, first one sings a song and then the other. The singing and see-sawing continue until one or the other runs out of verses. Sometimes others in the party take the places of those who have just finished and either repeat verses or begin a new series constituting a new rune. The meter is unrhymed. It is like that in Longfellow's "Song of Hiawatha." In fact, Longfellow was so impressed with the Kalevala that he admittedly patterned his song after it and it is said even borrowed some of the characters and incidents. The singing is accompanied by the playing of the kantele, an instrument similar to the dulcimer. The music itself is in a minor key and as it is sung resembles more nearly a chant than a melodious air.

The Kalevala, composed as it is of the folk-songs of a people largely if not wholly dependent upon their own ingenuity for the gaining of a livelihood, is really the story of the struggle of the

Finn to overcome the titanic handicaps set against him by nature. His "land of a thousand lakes" is a land of *thousands* of lakes, a land of vast swamps with only here and there a diminutive area suitable for cultivation. The lowland depressions invite premature frosts which often destroy in a night crops representing the hard labor of many months. No surplus of foods to be consumed during periods of scarcity can be accumulated where frost is master. Not only are products of the soil scant, but raw materials for manufactures are limited. The hardy forests for lumber and pulp and the numerous rapids for power send a ray of hope down the Finn's uncertain pathway toward success. Yet in the face of these limitations the Finn has plodded on patiently and uncomplainingly until to-day he has attained a place among the peoples of the earth which many may well envy.

The Finnish farmer is constantly threatened by frost. He knows not when or where it will fall next. A robber-band could hardly worry him more, for there would be some hope of resistance or escape, but the frost is not to be fought nor does it discriminate as to its prey. No wonder, then, that in the national epic Frost is personified and its destructive propensities narrated. In Rune 30 of the Kalevala, Frost interrupts the progress of Lemminkainen, one of the four heroes of the story, who proposes an attack against Pohjola, the North Country. (This region is now represented by Lapland.) Here he had previously gone upon an unsuccessful venture to woo the daughter of Louhi, Mistress of Pohjola. Lemminkainen remonstrated with Frost in no uncertain terms and describes him as follows:

> . . . Evil-born and evil-nurtured,
> Grew to be an evil genius,
> Evil was the mind and spirit,
> And the infant still was nameless,
> Till the name of Frost was given
> To the progeny of evil.
>
> Then the young lad lived in hedges,
> Dwelt among the weeds and willows,
> Lived in springs in days of summer,
> On the borders of the marshes,
> Tore the lindens in the winter,
> Stormed among the glens and forests,
> Raged among the sacred birch-trees,
> Rattled in the alder branches,
> Froze the trees, the shoots, the grasses,
> Evened all the plains and prairies,
> Ate the leaves within the woodland,
> Made the stalks drop down their blossoms,
> Peeled the bark on weeds and willows.

The heavenly bodies as well as the elements of the earth are humanized and deified. They are removed and replaced and caused to perform as circumstances may dictate, with a facility such as characterizes the most magnificent flights of the imagination. Louhi, Mistress of Pohjola, hides the Sun and Moon when the heroes Ilmarinen, Wainamoinen and Lemminkainen organize an expedition against her in order to rob her of the Sampo—"the talisman of success." Her resistance is finally overcome and she is forced to restore the Sun and Moon. The restoration (in Rune 49) is accomplished and Wainamoinen, Son of the Air and of the Virgin of the Atmosphere, a minstrel of magic power, observes the return of these heavenly bodies and recites as follows:

Greetings to thee, Sun of fortune,
Greetings to thee, Moon of good-luck,
Welcome sunshine, welcome moonlight,
Golden is the dawn of morning!
Free art thou, O Sun of silver,
Free again, O Moon beloved,
As the sacred cuckoo's singing,
As the ring-dove's liquid cooings.

Rise, thou silver Sun, each morning,
Source of light and life hereafter,
Bring us, daily, joyful greetings,
Fill our homes with peace and plenty,
That our sowing, fishing, hunting,
May be prospered by thy coming.
Travel on thy daily journey,
Let the Moon be ever with thee;
End thy journeyings in slumber;
Rest at evening in the ocean,
Glide along thy way rejoicing,
When thy daily cares have ended,
To the good of all thy people,
To the pleasure of Wainola,
To the joy of Kalevala!

A cheerful aspect of the Finnish environment is presented in the Farewell song (in Rune 24) of the daughter of Pohjola who has become bride of the smith and craftsman Ilmarinen. This song paints a landscape to whose attractiveness those can well attest who have tramped across Finland's fens or through her forests.

Send to all my farewell greetings,
To the fields, and groves, and berries;
Greet the meadows with their daisies,
Greet the borders with their fences,
Greet the lakelets with their islands,
Greet the streams with trout disporting,
Greet the hills with stately pine trees,
And the valleys with their birches.

Fare ye well, ye streams and lakelets,
Fertile fields and shores of ocean,
All ye aspens on the mountains,
All ye lindens of the valleys,
All ye beautiful stone lindens,
All ye shade trees by the cottage,
All ye junipers and willows,
All ye shrubs with berries laden,
Waving grass and fields of barley,
Arms of elms, and oaks and alders,
Fare ye well, dear scenes of childhood,
Happiness of days departed.

Ilmarinen returns (in Rune 25) to Wainola with his Pohjola bride, to receive an heroic welcome at the hands of Lakko, hostess of Wainola. Lakko recounts in great detail the numerous comforts awaiting the bride and concludes with a few effective words descriptive of the village setting. This description characterizes equally well a typical Finnish farm location of the present day.

Thou hast here a lovely village,
Finest spot in all of Northland,
In the lowlands sweet the verdure,
In the uplands, fields of beauty,
With the lake-shore near the hamlet,
Near thy home the running water,
Where the goslings swim and frolic,
Water-birds disport in numbers.

The Finn's favorite trees are the gracefully clustered white-trunked birch, the stately symmetrical towering evergreen and the cheerful red-berried mountain ash. The birch is the most economic tree, for in addition to fuel it supplies numerous utensils. Wainamoinen (in Rune 44) wandering across the field and through the forests seeking his lost kantele, comes upon a weeping birch. He inquires into all this sadness and the tree responds as follows:

. . . I, alas! a helpless birch tree,
Dread the changing of the seasons,
I must give my bark to others,
Lose my leaves and silken tassels.
Often come the Suomi children,
Peel my bark and drink my life-blood;
Wicked shepherds in the summer,
Come and steal my belt of silver,
Of my bark make berry baskets,
Dishes make, and cups for drinking.
Oftentimes the Northland maidens
Cut my tender limbs for birch brooms,
Bind my twigs and silver tassels
Into brooms to sweep their cabins;
Often have the Northland heroes

> Chopped me into chips for burning;
> Three times in the summer season,
> In the pleasant days of springtime,
> Foresters have ground their axes
> On my silver trunk and branches,
> Robbed me of my life for ages.

Thus the valued birch acquires personality and through the words of the folk-song permanent expression is given to the Finn's appreciation of its services.

No discussion of Finnish life could possibly be considered complete without reference to the bath. The Finn swears by the bath. It is an institution of no mean value, for it not only helps him preserve his health but, to his mind, serves also as a cure for all ills. The bathhouse is one of the first of the numerous structures to be erected upon a Finnish farm site. It is a small frame shack containing a glacial-boulder fire-place. The fire-place projects well into the room and is without a chimney. A hole in the roof of the building permits the smoke to escape, or sometimes the cracks between the timbers are relied upon as substitutes for the chimney.

In the preparation of the bath, the stones of the fire-place are first heated to a high temperature. Then the fire is put out and cold water is thrown upon the stones. Great clouds of condensed steam fill the room. Around the walls of the room are shelf-like platforms upon which the bathers lie. As the steam stimulates the blood circulation, the bather beats himself with a bundle of birch or aspen twigs. After some ten or twenty minutes immersion in the steam, he enters a small adjoining room and there throws cold water upon himself. The cold "shower" is sometimes applied out-of-doors instead of in a room. He then retires to his house to dress. In winter it is not unknown for a bather to roll in the snow immediately after the bath. The shock of course is great, but with training from childhood the Finn withstands the ordeal and develops tremendous physical endurance.

The Finn's faith in the bath is unbounded and to find it immortalized in his national epic is rightly to be expected. In the "Birth of the Nine Diseases," (Rune 45), there follows an interesting description of the bath and a prayer that its curative qualities may endure:

> Wainamoinen heats the bathroom,
> Heats the blocks of healing sandstone,
> With the magic wood of Northland,
> Gathered by the sacred river;
> Water brings in covered buckets
> From the cataract and whirlpool;
> Brooms he brings enwrapped with ermine,
> Well the bath the healer cleanses,

Softens well the brooms of birch-wood;
Then a honey-heat he wakens
Fills the room with healing vapors,
From the virtue of the pebbles
Glowing in the heat of magic,
Thus he speaks in supplication:
"Come, O Ukko, to my rescue,
God of Mercy, lend thy presence,
Give these vapor baths new virtues,
Grant to them the powers of healing . . ."

Reference has been made to the minor key in which these runes are sung. Finnish music is impressive because so full of character. Its melodies reveal nature's severity, yet they also reflect her forebearance. Life is never so hard but that it has its compensating days. So the minor key reflects at times a somewhat sombre atmosphere and a certain degree of sadness, yet the absence of heavy accents helps to create a feeling of hopefulness and high spirit. One easily recognizes the rushing streams with alternating rapids and reaches, or the clear sparkling glacial waters playing in the brilliant northern sunshine. Nature seems to direct in every song.

The Finn, stolid and phlegmatic at times, but persevering and tenacious, possessed of remarkable physical endurance and a stout heart, has given his brain cells opportunity for growth. His countrymen show the highest percentage of literacy among the nations. He loves to read. In his long hours of solitude he digests his readings and allows his imagination full freedom to build upon the ideas absorbed. Thus the Finn has evolved a vivid imagination which has contributed to the development of literature of exceptional merit. His poetry, including both folk-songs and modern works, having been conceived amid the influences of nature, show her unmistakable impress. The reflection of the environment is perfect, and in the Kalevala, especially, the character of Finnish life is accurately and strikingly imaged.

WHAT IS INTELLIGENCE AND WHO HAS IT?

By Professor LIGHTNER WITMER
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INTELLIGENCE is the ability to solve a new problem. An unsurmounted difficulty is a new problem so long as its solution is unknown. It is easy enough to cut the Gordian knot, or to stand an egg on end, after one has learned how these historic intelligence tests were solved. When a problem is difficult enough, or the solution sufficiently novel and important, the intelligence displayed in successful invention will be considered "genius."

Life confronts us with problems, new and old. Just to keep one's self alive is a very old one. "To live by one's wits" is to solve it by an exercise of intelligence. From the cunning of a horse trader to the genius of an Aristotle is a long step up on the scale of intellectual competency; but intelligence may appear at any intellectual level, even a low one, and is divined from what the individual makes of opportunity and resources. We ascertain how much knowledge and skill enter into a performance in order to disregard them, for the intelligence displayed in successful adventure is measured not by the resources employed, but by the risks involved and the difficulties overcome. If, for example, the Russian Soviet is in fact a weak form of government, and the Bolshevists are as entangled in ignorance, insanity and crime as would appear from the reading of our daily newspaper, then it follows that the intelligence of a Lenine or a Trotzky must be given a higher rating than the genius of statesmen who have tried in vain to sink this defective ship of state, despite the fact that they have had at their command the intellectual resources of the most cultured and efficient nations of the world. Intelligence is not to be measured by conventional standards, but by the successful outcome of performance. The discrimination of intelligence from other abilities is concerned only with the criteria that distinguish the variable and novel creations of free initiative from the more constant and familiar effects of established habits. The originality of a performance is proportional to the number of novel elements entering into its composition, and to the amount by which a successful creation of the productive imagination varies from the prevailing mode.

The really serious problems of daily life, the primeval and yet

recurrent problems of mere existence were solved long ago by our pre-human ancestors. As a consequence, we are now able to get up in the morning, cook and eat our breakfast, swallow and digest it, without an exertion of intelligence or intellect, employing for the purpose inherited habits which are physiological mechanisms called "instincts" and "reflexes." Throughout a busy day, full of varied performance, one gets on with the day's work, solving problem after problem, many of them difficult enough, some of them possibly beyond the proficiency of all but the most expert or the best informed; but rarely will a new problem emerge from the comfortable routine of a well-ordered existence.

Education is the device of civilization to keep us from encountering new problems. The method employed is showing the pupil how to solve problems instead of letting him solve them for himself. It thus makes the exercise of his intelligence unnecessary. The school presents the paradigm, and when life confronts the graduate with a new problem, he solves it by virtue of an acquired intellectual habit, and in conformity to the scholastic model.

Endow a child with intellect, let him acquire knowledge and efficiency, teach him to conform his conduct, thought and feeling to the prevailing mode, and you go far to assure him a useful life at a high intellectual level. If he has intelligence, it may facilitate the schoolmaster's task, but pupil and teacher can, and do, get along without it. They must, however, avoid an excess of stupidity. They must not try to solve new problems if every attempt brings failure. They must do what the timid do, who fear failure more than they desire success; they must check initiative, censor the imagination, suppress revolt, curb aspiration and refrain from adventure. At this task the pupil will be aided and abetted by the greater number of schoolmasters who will direct his progress from the first year of the elementary school to the commencement day, which yields the certificate of intellectual proficiency called a "diploma." To discover how much intelligence the graduate of this educational system really has, one would have to surprise him at a moment when he is confronted by some accidental obstacle in an otherwise well-ordered existence—a missing suspender button, for instance, for which he must quickly invent a substitute, or some other difficulty connected with the sempiternal problem of making both ends meet.

Competency is an aggregate of many congenital abilities, some of them specific abilities, like talking and singing; others more general, like intelligence, intellect, discernment, will and motivation. By the time a child is six years old he will ordinarily display

all his congenital competency, from which the discerning observer may estimate how much ability he has and judge if he has enough to be considered normal. Let six-year-old children of normal competency grow up without instruction in school subjects, and therefore below the point of literacy on the intellectual scale, and they will be arrested in development at the level which defines the low grade imbecile. Let them, however, grow in stature, strength and endurance, in social conformity and sexual proficiency, and they could raise and support a family, if it were not for the difficulties provided by what in our pride we call "civilization." During the war, some imbecile children in the city of Philadelphia, arrested under the compulsory education law, were earning more than the truant officer who arrested them. It is not the inherent difficulty of earning a living and raising a family which makes the task impossible for those whose mental age is not more than six years; it is the grocer, the landlord and the employer, competitors whom they must outwit in the struggle for existence, ease and comfort. Civilization implies an average intellectual level. The farther a man's intellectual level falls below the mode, the more intelligence he will need.

No one has ever devised an intelligence test that tests intelligence and nothing else. In consequence, the results of so-called intelligence tests have significance only when analyzed and interpreted in relation to a particular set of antecedent conditions and attending circumstances. The Binet intelligence quotient, for example, is a measure of proficiency, and in those making low scores it may indicate anything in the way of ability or deficiency except intelligence. We do not observe or measure intelligence—we observe performance and measure its effects. A few intelligent performances will cause us to anticipate more of the same sort, and even an intelligent look may lead us to expect intelligent behavior. Intelligence is not a fact, but an explanatory concept derived from the observation of facts. It is a diagnostic category like courage or honesty, the diagnosis being in effect the verbal expression of an expectation.

In order to test the ability to solve a new problem, an intelligence test must provide that many members of a homogeneous group will fail, and that all but a few will make many errors before they achieve success. Those who make many attempts in a given time are more likely to succeed than those who make only a few attempts. Intelligence, therefore, is directly proportional to initiative and inversely proportional to the number of errors made, provided the errors are not too few. To measure a performer's intelligence one must know the time required to achieve success, but one must

not neglect to observe the performer at work and to take into the consideration the number and kind of errors made and how he corrects them. Intelligence is displayed through the operation of trial and error. An intelligence test is adjusted to the intellectual level of a group when those who succeed do not outnumber those who fail.

At the Psychological Clinic, an eleven block formboard is employed as an intelligence test. It may be solved in eleven moves in about eleven seconds, but anyone who solves it thus displays efficiency not intelligence. This formboard is an intelligence test at or about the four year old intellectual level, because not more than 50 per cent. of four year old children are able to solve it, even with a time allowance of one hundred seconds. No two year old child has ever passed the test; about 25 per cent. of three year old children have passed it, and approximately 100 per cent. of six year olds. If I know nothing about a particular child except that he is four years old, the odds are even that he will pass the test. If he is three years old, the odds are three to one that he will fail.

Intelligence is displayed in a performance that succeeds against adverse odds; stupidity is failure despite favoring odds. At any moment a future of some sort confronts us, and often we have nothing better than a gambler's guess for guide. When the odds favor failure, we have only a gambler's chance of winning; if we plunge and win despite the adverse odds, we have had a gambler's luck. The success of an intelligent player who uses all the resources at his command to win a fortune, whether at cards or in business, has a very different diagnostic significance from the "dumb luck" of inheriting money or finding it.

Intelligence, then, is a successful leap into the dark. "A man never rises so high," said Oliver Cromwell, "as when he knows not whither he is going." Converting the words of a madman into a slogan of success, Browning thus portrays the morale of the adventurer at the critical moment when success or failure hangs upon the issue of performance:

> There they stood, ranged along the hillsides, met
> To view the last of me, a living frame
> For one more picture! in a sheet of flame
> I saw them and I knew them all. And yet
> Dauntless the slug-horn to my lips I set
> And blew, "Childe Roland to the Dark Tower came."

The achievement of intelligent initiative may be a successful adventure of pioneer or conqueror, the creation of a work of art, a new idea, an invention—some performance, no matter what, so

long as it be original to the performer, the product of an imagination that outruns knowledge, of an ingenuity that outdoes skill.

If this is a novelty to the beholder, it may inspire admiration, appreciation or wonder. If it is too novel, it will arouse distaste, fear and a destroying hatred. The more shocking a product of the creative imagination, the greater the presumption that genius inspired it, provided the production is something worth while.

The American readers of Walt Whitman's "Leaves of Grass" were too shocked to appreciate the singular novelties of thought and diction concealed beneath the innocent botanical title. When he walked the streets of Philadelphia and Camden, he was ignored by those whom a recent French critic calls his "rustic compatriots." Now that French and English writers have discovered him to be the most original of American poets, his peculiar genius is not without honor even in his own country, save only perhaps in those classic centers of intellectual conservatism—the departments of English literature in our universities.

The Declaration of American Independence started a long war; it eventuated in a form of government as new to the Europe of that day as the Russian Soviet is now; it enthused and emboldened the French Revolutionists; it brought in its train the doctrine of self-determination; it helped to promote the Russian revolution and the success of the Irish Sinn Fein; it was signed by men who felt the hangman's noose about their necks, and only the successful outcome of the adventure kept the noose from being drawn tight.

Whitman says:

> I am the sworn poet of every dauntless rebel the world over.
> I do not know what you are for (I do not know what I am for myself, nor what anything is for),
> But I will search carefully for it even in being foil'd,
> In defeat, poverty, misconception, imprisonment—for they, too, are great.
> Revolt! and still revolt!

American patriots, those in particular who would be considered sons or daughters of the Revolution, ought to bear tenaciously in mind that resistance to constituted authority, as well as intelligence and compromise, went into the making of our Constitution.

Intelligence, then, plays a lone hand. It is individualism rampant, and may stake livelihood, happiness, life itself against the opinions and concerted actions of a public horrified by the strangeness of its creations. It is a minor group trying to outplay the majority. It is youth and inexperience trying to outdo old age and wisdom. It is eccentricity successfully opposing the prevailing mode.

The judgments of society, like the verdicts of juries, are not always easy to predict, and are susceptible to strange and rapid

transmutation. Not more than a century ago a Unitarian could be stoned on the streets of Boston. To-day, a Unitarian is Chief Justice, a member of the most conservative branch of one of the most conservative governments in Christendom. John Brown's body hardly lay a-mouldering in the grave before his soul went marching on at the head of forces, military and political, which made possible Lincoln's "Emancipation Proclamation," a document destroying much private property, but, nevertheless, acceptable to what had become, by then, the dominant opinion in American politics. When Socrates was condemned to death, his moral teachings were, by due process of law, adjudged subversive of religion and good government, a source of corruption to youth. "When men revile you and persecute you, for My sake, rejoice and be exceeding glad, for great is your reward in Heaven, for so persecuted they the prophets which were before you."

The non-conforming genius appears to lose; but once dead and safely buried, he lives in monument and story, the stakes he plays for being held by the unborn, while those who seemingly outplayed him join the unknown multitudes that survive, if at all, only in their progeny.

What, then, is success? It is the approbation of the many, or a few, now or at some future time. In the last analysis, it is what the individual himself deems worth while. Originality, therefore, is appreciated non-conformity. Intelligence is successful eccentricity. It is energy so controlled and directed that a worth while pattern of performance is created. Except for the necessity of conforming to some standard of appreciation, and it may be merely self-appreciation, intelligence is free initiative, unconstrained by definite ends. To exercise a man's intelligence, he must be left free to do what he desires; he must be given every opportunity to make mistakes, in the hope that he will profit by experience. If a child falls down, don't pick him up unless he is in imminent danger—let him learn to pick himself up. If men fall into error, don't correct them by telling them the truth; let them flounder in error until they find out the truth for themselves. This is Nature's way of promoting intelligence.

When our first schoolmaster entered the Garden of Eden in the guise of a serpent, and forced Eve to choose between innocence and knowledge, he made the oldest recorded test of human behavior, and Eve responded to it with intelligence. If this "first disobedience brought death into the world and all our woe," it also brought what we hold dear—civilization (we thought it worth fighting for), the home, the church, the state, our educational system, private property and the inventions of intellect and art. Without fully

realizing what she was doing, Eve rejected a life of ease, comfort and machinelike perfection, choosing the hard and devious path that led from Paradise to the civilized communities which harbor her descendants. Her choice assured them a life of toil, discontent and conflict, all the trouble necessary to exercise their intelligence, train their efficiency and develop their intellect. What more successful outcome would you ask of a simple venture into the unknown, inspired by hardly more than curiosity, motivated by discontent, and determined, it would seem, by the spirit of revolt against authority? Curiosity is the mother urge of science and truth; discontent awakens aspiration, and amongst the traits of character most frequently associated with creative imagination are ambition, audacity, aspiration, the love of adventure, and, most significant of all, a disregard of authority, leading perhaps to the defiance of privilege and public opinion. "He had every quality of a great commander except insubordination," Lord Fisher said of the British admiral who lost, or won, the battle of Jutland.

To teach a student to think for himself is to teach him to disregard authority, including his teacher's. For this reason it is not a common practice of the teaching profession, although it receives much enthusiastic verbal appreciation. Parents, however, are not at all hesitant about expressing their disapproval when a child produces some new idea contradicting well-established convictions. The father of Richard Feveril states a parental ideal in these words: "I require not only that my son should obey. I would have him guiltless of the impulse to gainsay my wishes." He would have added "opinions" could he have conceived it possible for these to be called in question.

Freedom of thought began with the liberty of conscience so outspokenly maintained by the Hebrew prophets, of whom the greatest was also the last, the apostle Paul, who borrowed the characteristic freedom of Hellenic thought to project a new religion. Christianity has fostered freedom of thought and action, though not excessively nor hurriedly. Intellectual, like material, possessions are acquired arduously, and, once acquired, they are held with the same bitter tenacity—the old time religion, the old Constitution, the ancient literature and even that intellectual absurdity—the old science. A mother recently wrote to the dean of a scientific school, asking whether a boy who studied engineering there would be exposed to the theory of evolution, because if this were possible, she proposed to send him to some other school. "Why does a professor have to introduce new and debatable topics for discussion in the classroom?" I have heard the question asked even in academic circles. "Isn't there a large enough body of safe

and sane knowledge to occupy his brief periods of instruction?" No doubt the professor is free enough in some institutions to say what he wishes, but the joker is—the professor does not want to say what will subject him or his institution to hostile criticism. For this reason, university faculties do not make a brilliant display of creative intelligence in the intellectual field. Our educational system, as a whole, is distinguished by the conformity it promotes, the mental discipline it trains.

This, doubtless, is as it should be, for successful living is at least ninety-nine parts in a hundred conformity and constraint; only a very small fraction of one per cent. of a man's life can, at the very best, display freedom of thought and action. In no field, however, is it so important to keep the little freedom we have as in the field of intellectual production. And yet thought is so rigidly conformed in this country to 100 per cent. patterns that American genius is not conspicuous for intellectual originality. Some years ago I heard a professor at the University of Rome express the opinion that the development of big business in the United States was an outburst of creative energy similar to that which distinguished Italy during the Renaissance. Do not go to our universities to observe the best American intelligence in action; go out into the business world where great enterprises are successfully put over. There the atmosphere is one of freedom—even from the constraint of honesty and truth. This year the winner of the Nobel prize in literature is Anatole France, an avowed communist; another winner is Premier Branting, the leader of the dominant socialistic party in Sweden. Representative American contributions to art are movies and jazz bands, skyscrapers and railway stations. When America honors the free expression of new ideas without regard to their normalcy, intellectual originality, as well as mechanical invention, may become a conspicuous trait of American character.

The meeting place of intellect and intelligence is interesting. Imagination belongs to the category of intellect, and also to the category of intelligence. Creative imagination produces order out of chaos. As soon as a little child can use the kindergarten peg board, give him one and ask him to put the pegs into the board. He puts in the first one; where shall he put the second, beside the first or at a distance? This is the critical moment. If he puts it, let us say, beside the first, it must be to the right, to the left, above or below. He is now ready to put the third peg in position. If he does what he did with the second peg, he will make a row. A plan appears, a definite order is displayed. If he works without instruction he is producing an order of his own. He is doing

something that has meaning. He displays creative imagination. He is already beginning to develop an intellect. As the spider spins a web from his own body, so the human being weaves patterns of performance, establishes order, rises superior to chaos and produces standards of behavior based on knowledge. This employment of intelligence in intellectual organization is characteristically and typically human. I have tested chimpanzees and other apes, but have never known an ape to create a new order of his own. I have not seen a chimpanzee peg a straight line of his own accord, but I have observed little children doing it as soon as they could grasp the pegs and put them in place.

A civilization is a social order, the average developmental level of a group, it may be large or small. It is to be measured by the number and diversity of material and intellectual resources, but its chance of survival depends on intelligence, that is to say, on its ability to change. The social order of to-morrow is the invention of the few whose intelligence operates at a high intellectual level.

Change is the predominant characteristic of uterine life; stability, of the adult. At what age does the individual begin to stand pat? When does a man lose the ability to get a new idea, to change convictions or a point of view? At any age. Some, indeed, never get a new idea. They imitate in thought the prevailing modes of the social group to which they happen to belong, or to which they aspire. Fifteen, however, is an age at which a great number, perhaps the majority of those who do at least a little thinking of their own, harden into conventional patterns of thought and behavior. Others keep changing and growing intellectually up to thirty, some even up to forty-five, while just a few display to the very end that intellectual pliability which is intelligence informed by acquired knowledge.

A new individual begins to exist at conception with the union of a spermatozoon and an ovum. He will change more during the nine months of uterine life than in the remaining years of his existence. At birth, it has been estimated, he will possess only two per cent. of the original energy of development. He is like a clock, wound up at conception, which keeps running down until it stops at death. At twenty-one he comes of age, able to inherit the family property but already at six years of age he has entered into his heritage of human competency, and has begun to develop his natural resources of intellect and character, of intelligence and skill.

Age advances on a very uneven front. Long before the first gray hair or the first wrinkle, some congenital abilities have hardened into particular modes of behavior. It is then difficult, if not impossible, to change old habits for new. A child, for example,

having learned one language with ease, inclines to stand pat on his accomplishment. He appears to lose some of his original pliability, offers resistance to the acquisition of another language, develops a sort of organic obstinacy, in other situations called "constitutional conservatism." From infancy on, efficiency is being acquired at the expense of general competency. Problems are solved with increasing accuracy and speed, but the ability to solve new problems is greater at the age of six years than at any later period. Youth combines the plasticity of initiative with the efficiency of acquired skill, and thus produces the successful inventions from which a new order is evolved. Old age brings wisdom, but is handicapped by a deficiency of initiative and dislike of change. The vitality of a civilization is directly proportional to the creative intelligence of its young men and young women.

Observation of the behavior of children and adults leads to the conclusion that education can not make the stupid intelligent. Intelligence is a congenital though not inherited endowment, and the amount of it can not be increased by training. Genius is not a product of breeding; its appearance is in the hands of the gods, a result of the fortuitous combination of qualities possessed by the germ plasms entering into the conception of a new individual. The chief condition which appears to favor superior intelligence is the variety of race and family mixture. The more mongrel a people, the more intelligent; the purer the blood, the more stupid. Intelligence would seem to require an inner conflict of cross purposes and opposing impulses. Neither the Jew, the Anglo-Saxon, the Irish, the French, the Italian nor the American is pure-blooded, in comparison with the Prussian Junker, whose blood is purer and older than the oldest of first families in England or America.

In an essay on "Race and Tradition," written more than twenty years before the great war, Darmesteter, a Frenchman, says of Germany: "The misfortune of Germany—what constitutes her momentary strength and will bring about her lasting weakness in the future—is that the element of race is better preserved there than elsewhere. Hence, narrowness of spirit, lack of proportion in her intelligence, of justice in her heart. She lacked that fruitful struggle of contrary forces that limit their excesses by complementing their energies, and that, in recognizing their mutual rights, enlarge the innate narrowness of man, with the result of producing something that has the extent and variety of Nature herself. Germany has remained, and still remains, a thing strangely powerful and painfully incomplete." [1]

[1] Selected Essays, translated by Helen B. Jastrow.

Two hundred years ago, the author of "Robinson Crusoe" paid his respects to those who tried to mobilize the race prejudice of "true born Englishmen" against the followers of William of Orange, in words that some of our "hundred per cent. Americans" might ponder with profit:

> These are the heroes that despise the Dutch,
> And rail at new-come foreigners so much;
> Forgetting that themselves are all derived
> From the most scoundrel race that ever lived;
> A horried crowd of rambling thieves and drones
> Who ransacked kingdoms and dispeopled towns;
> The Pict, and Painted Briton, treach'rous Scot;
> By hunger, theft, and rapine, hither brought;
> Norwegian pirates, Buccaneering Danes,
> Whose red-haired offspring everywhere remains,
> Who join'd with Norman French, compound the breed,
> From whence your true-born Englishmen proceed.

There are those who fear for civilization. Of what are they afraid? Civilization is not necessarily threatened, whether by imperialists or communists; *our* civilization may be—the aggregate of our material and intellectual possessions. Creative intelligence, however, is indifferent to the language which transmits the intellectual fruits of man's genius—whether it be Anglo-Saxon or Prussian, Latin or Slav, indifferent even to the color of the hand that bears aloft the torch of enlightenment and progress, let it be yellow, white or black. So far as intelligence and progress are concerned, the future is a sporting proposition, and the sportsman's attitude is to let the best man win.

The general aim of civilization is dominion over nature—the more efficient control of natural forces. There are doubtless some who still think that man's subjection to nature is a law of God, and that a social order once established must not be changed. Progress, however, is inevitable, though privilege and authority, timidity and prejudice will always oppose the creative advance of intelligence. To defy the spirit of progress in the name of either religion or law is superstition; the true prophet is a poet who sees in creative evolution the display of divine intelligence.

What the world needs to-day is more of the optimism of the progressive and a little less of the pathological fear of the standpatter, more faith in creative evolution, more hope of reaching yet higher levels of achievement and more of that freedom from prejudice called charity, another name for love, the productive passion.

SOCIAL LIFE AMONG THE INSECTS[1]

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Lecture II. Wasps Solitary and Social

In the preceding lecture I gave a brief account of the rudimentary social life of certain beetles and called attention to the fact that in all or nearly all of them the male cooperates with the female parent in victualing or protecting the offspring. I endeavored to show that all these societies have their inception or *raison d'être* in the specialized feeding habits of the parents and that in all of them the food is of vegetable origin, abundant but not very nutritious in some of the cases (dung and rotten wood in the Scarabæidæ, Passalidæ and Phrenapates), in others highly nutritious, but obtainable only in small quantities at a time (living plant-tissues and honey-dew in the case of the Tachigalia beetles, ambrosia of the Ipidæ and Platypodidæ). The adequate exploitation of such food-supplies is necessarily time-consuming and has evidently led to a lengthening of the adult lives of the beetles. This in turn has naturally brought about an overlapping of the juvenile by the parent generation, thus enabling the parents to acquire contact and acquaintance with their young and an interest in providing them with the same kind of food as that on which they themselves habitually feed. In the insects which I shall consider in this lecture, we find a series of societies originating in a very different type of feeding and leading to much more complicated and more definitely integrated associations.

Although the wasps have attracted fewer investigators than the ants and bees, they are of even greater interest to the student who is tracing the evolution of specialized instincts and social habits. The wasp group is one of enormous size and is really made up of two great complexes, the Sphecoids and the Vespoids, together comprising more than a dozen families and some 10,000 species. Of these only about 800 are clearly social. We have more or less fragmentary behavioristic studies of scarcely 5 per cent. of all the species. Yet they cover a sufficient number of forms to enable us to establish the following generalizations:

(1). The structure and behavior of the Sphecoids and Vespoids

[1] Lowell Lectures.

show that they must have arisen from what have been called Parasitic Hymenoptera, and the structure of the ants and bees shows that they in turn must have arisen from primitive Sphecoids or Vespoids.

(2). The social wasps comprise several groups which have evolved independently from primitive, solitary Vespoids, but there are also a few Sphecoids that exhibit subsocial propensities.

(3). Both the Sphecoids and the Vespoids are primarily predaceous and feed on freshly captured insects, but the adults are fond of visiting flowers and feeding on nectar. Some social wasps store honey in their nests, but it is probably not an exclusive or essential constituent of the larval food. One small and aberrant group of solitary Vespoids, the Masarinæ, however, provision their cells with a paste of honey and pollen, like the solitary bees. The insect prey on which at least the young of nearly all the wasps subsist, being extremely rich in fats and proteids, is an ideal food, but has to be provided in larger quantity than such concentrated vegetable substances as pollen and nectar. It is also scarcer and more difficult to obtain. Hence the definite tendency in adult wasps towards a honey regimen at least for the purpose of eking out the primitive animal diet.

(4). We are able to observe in the social wasps more clearly than in other social insects the peculiar phenomenon which I have called "trophallaxis," *i. e.*, the mutual exchange of food between adults and their larval young.

(5). The study of the wasps and of their ancestors among the Parasitic Hymenoptera furnishes us with a key to the understanding of parthenogenesis and the peculiar dominance of the female sex (gynarchy) which is retained throughout the whole group of stinging Hymenoptera (wasps, bees and ants).

(6). In the social wasps we witness the first gradual development of a worker caste and also of polygyny and swarming.

(7). We observe in wasps a high degree of modifiability of behavior and an extraordinary development of memory, endowments which have led McDougall to claim for them "a degree of intelligence which (with the doubtful exception of the higher mammals) approaches most nearly to the human," and Bergson to point to their activities as one of the most telling arguments in favor of his intuitional theory of instinct. Although I believe that these and many other authors have been guilty of some exaggeration the wasp's psychic powers compared with those of most other insects or even of many of the lower Vertebrates seem to me, nevertheless, to be sufficiently remarkable.

We shall have to examine each of these generalizations more closely. Some of them may be considered forthwith, others more

advantageously after the description and illustration of a selected series of species.

Recent studies of the parasitic, or as I prefer to call them with O. M. Reuter, the "parasitoid" Hymenoptera, have revealed certain peculiar traits which recur in a modified form in the behavior of their Sphecoid and Vespoid descendants. But what are these parasitoids? You are all familiar with the fact that a large number of insects regularly lay their eggs on or in plants and that the hatching larvæ devour the plant tissues and eventually pupate and emerge as insects which repeat the same cycle of behavior. There is, however, another immense, but less conspicuous, assemblage of insects that lay their eggs on or in the living eggs, larvæ, pupæ and adults of other insects, and the eggs thus deposited develop into larvæ which gradually devour the softer tissues in which they happen to find themselves. Species that behave in this manner are not true parasites, but extremely economical predators, because they eventually kill their victims, but before doing so spare them as much as possible in order that they may continue to feed and grow and thus yield fresh nutriment just as it is needed. For this reason and also because, as a rule, only the larval insect behaves in the manner described, it is best called a "*parasitoid.*" The adult into which it develops is, in fact, a very highly organized, active, free-living creature, totally devoid of any of the stigmata of "degeneration" so common among parasites, and with such exquisitely perfected sensory, nervous and muscular organs that it can detect its prey in the most intricate environment and under the subtlest disguises.

The parasitoids exhibit another peculiarity which was destined to acquire great importance in their descendants, the wasps, bees and ants, namely, parthenogenesis, or the ability of the female to lay unfertilized eggs capable of complete development. As a rule, if not always, these parthenogenetic eggs develop into males, whereas fertilized eggs laid by the same female develop into individuals of her own sex. Thus the female has become to some extent independent of the male in the matter of reproduction. It will be seen that if the parthenogenetic egg were able to develop into a female, as it frequently does in certain insects like the plant-lice, the male might become entirely superfluous. There are a few insects in which this has occurred or in which the male appears only at infrequent intervals in a long series of generations. But matters have not come to such a pass in the parasitoids or in the wasps, bees and ants, though these insects have perfected another method of reducing the male to a mere episode in the life of the female. Individuals of this sex are provided with a small muscular sac, the

spermatheca, which is filled with sperm during the single act of mating, and this sac is provided with glands, the secretion of which may keep the sperm alive for months or even years. According to a generally accepted theory, the female can voluntarily contract the wall of her spermatheca and thus permit sperm to leave it and fertilize the eggs as they are passing its orifice on their way to being laid, or she can keep the orifice closed and thus lay unfertilized eggs. The mother can thus control the sex of her offspring or if she has failed to mate, or has exhausted all the sperm in her spermatheca, may nevertheless be able to lay male-producing eggs. There seems also to be something compensatory, or regulatory, in this ability of the female parasitoid to produce males parthenogenetically, for if she be unable to meet with a male—and this predicament is very apt to arise among such small and widely dispersed animals as insects—she can produce the missing sex and thus increase the chances of mating for the next generation of females.

Certain facts indicate that the sex of the egg may not be determined in the manner here described, but their consideration must be postponed till they can be taken up in connection with the honey-bee. We are justified, notwithstanding, in regarding the female parasitoid, wasp, bee or ant, after she has appropriated and stored in her spermatheca all the essential elements of the male, as a potential hermaphrodite. The body, or soma, of the male, after mating, thus really becomes superfluous and soon perishes. In the solitary wasps the male is a nonentity, although in a few species he may hang around and try to guard the nest. But in the bees, ants and social wasps he has not even the status of a loafing policeman, and all the activities of the community are carried on by the females, and mostly by widows, debutantes and spinsters. The facts certainly compel even those who, like myself, are neither feminists nor vegetarians, to confess that the whole trend of evolution in the most interesting of social insects is towards an ever increasing matriarchy, or gynarchy and vegetarianism.

Now if we carefully observe a parasitoid while she is ovipositing in her prey, we obtain a clue to the meaning of the peculiar behavior of the solitary wasps which has led Fabre to certain erroneous conclusions and philosophers like Bergson to his peculiar interpretation of instinct. The parasitoid is furnished at the posterior end of her body with a well-developed ovipositor, a slender, pointed instrument for piercing the tough integument of her victim. But this instrument also has another function, namely, that of making punctures through which droplets of the victim's blood may exude and be devoured by the parasitoid. She may often be

seen thrusting her ovipositor into her prey without ovipositing and merely for the sake of obtaining food, or she may feed at a puncture she has made while ovipositing. Obviously feeding and oviposition are here congenitally, or hereditarily conditioned reflexes, to use Pawlow's expression. In other words, the internal hunger and reproductive stimuli, or appetites, are so intimately associated with one another that mere contact with the prey releases either the feeding or the ovipositing reactions, or both. And, of course, both of these reactions are purely selfish, the one being concerned with getting food, the other with getting relief from the discomfort of egg-pressure in the ovaries, and both may initiate elaborate trains or patterns of behavior (instincts). This is true not only of the parasitoids but also of insects in general.

Turning now to the solitary wasps we find that, like the parasitoids, they prey on other insects and that each species of wasp usually has a predilection for a particular species (Figs. 18 and 19), genus or family of insects, or even for a particular sex, as in the case of one of our common wasps, *Aphilanthops frigidus,* which preys only on queen ants. The chief difference

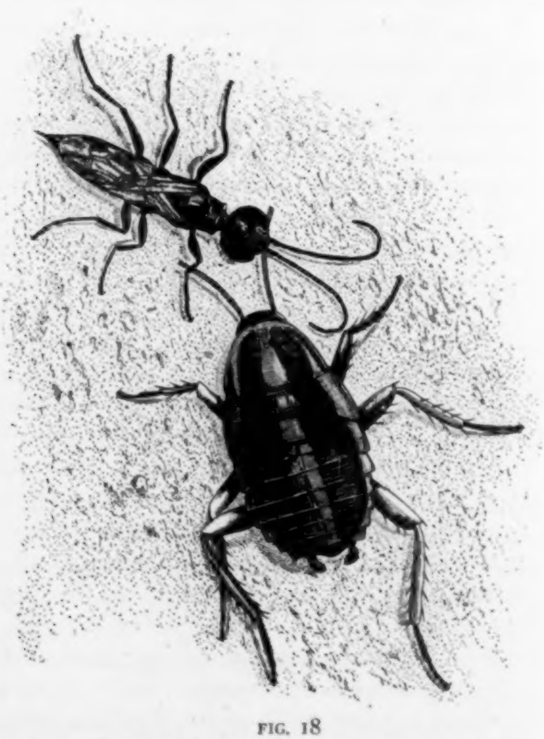


FIG. 18
Dolichurus stantoni of the Philippines dragging a young cockroach (*Blatella bisignata*) to her burrow. x 6. (After F. X. Williams).

between the parasitoid and the solitary wasp lies in the fact that the latter lays her egg on or near her victim after stinging it till it is motionless. The sting is merely the ovipositor which is now used only for defence or for reducing the prey to impotence, while the mouth-parts and especially the mandibles are used for obtaining food. Many solitary wasps, after stinging their prey,

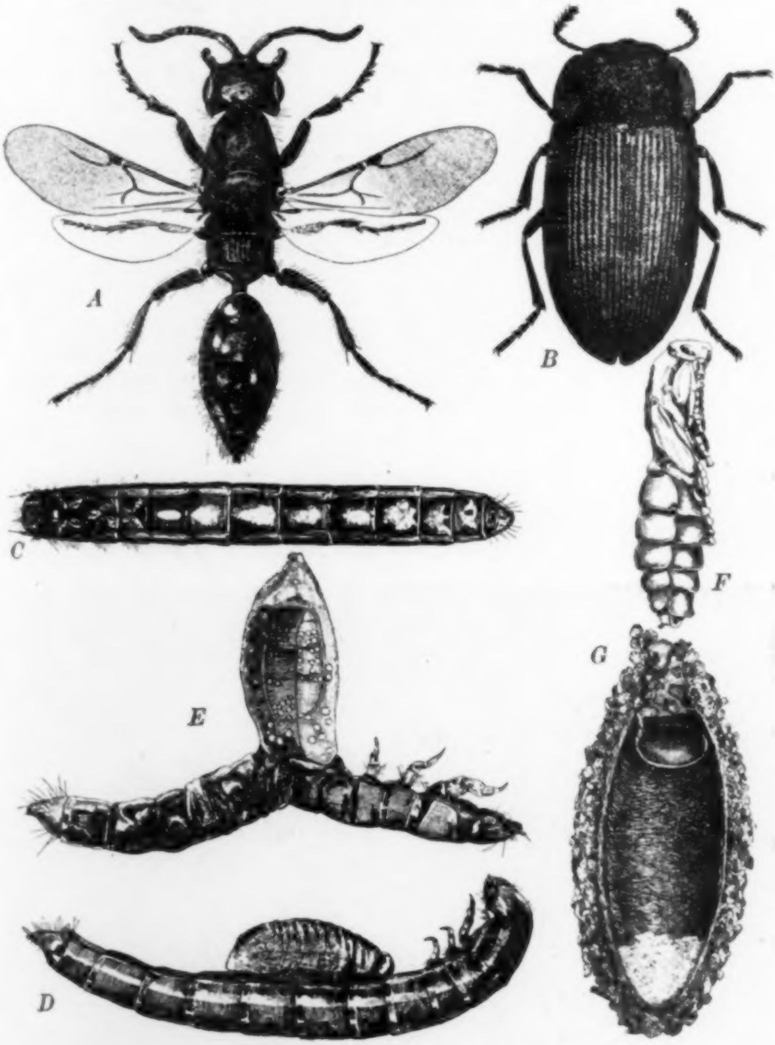


FIG. 19

A. Female of a Bethylid wasp *Epyris extraneus*, of the Philippines; B. Tenebrionid beetle, *Gonocephalum seriatum;* C. Larva of the same with egg of *E. extraneus* on middle of ventral surface; D. Young *E. extraneus* larva feeding on the larva of *G. seriatum;* E. Later stage of same; F. Pupa of *E. extraneus;* G. Cocoon of same. (After F. X. Williams).

devour it in part or entirely, or chew, *i. e.*, malaxate, its neck and lap up the exuding juices. This behavior is essentially like that of the parasitoid, and in its more frequent, feebler manifestations may be regarded as a vestigial feeding. The adult wasp is no longer as carnivorous as its ancestors, because she has come to rely to some extent on the energizing nectar of flowers, but this substance contains no proteids and is therefore an improper food for her growing larval young. Roubaud and Rabaud have recently shown that the stinging of the prey follows reflexly as soon as it has been seized and comes in contact with the wasp's sternum, and that the accidental position of the prey when it thus releases the reflex determines the point where it will be stung. Moreover, the stinging is repeated till the victim ceases to struggle and becomes motionless. Hence the stinging does not occur in the schematic manner nor necessarily in the nerve ganglia, as described by Fabre. It has also been shown that the venom introduced into the tissues of the prey by the sting produces paralysis or even death and also acts as an antiseptic in preserving the prey from decomposition for weeks or even months while the larva that hatches from the wasp's egg is feeding on the tissue, but these properties of the venom are accidental and unforeseen. Hence Fabre's and Bergson's contention that the solitary wasp is a clairvoyant surgeon, with an intuitive knowledge of the internal anatomy of the particular insect on which it preys, may be dismissed as a myth.

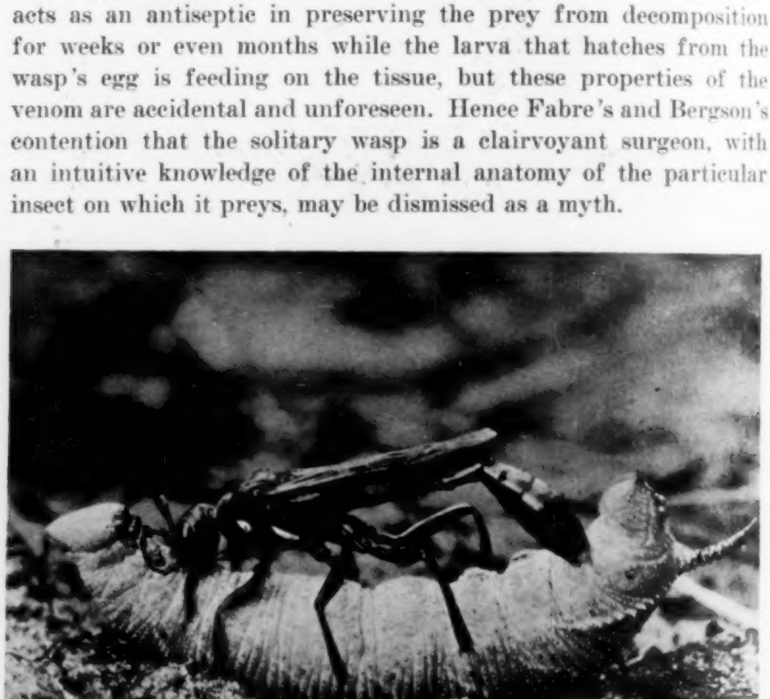


FIG. 20
Sphex procerus carrying caterpillar of sphinx moth to her burrow. (Photograph by Prof. Carl Hartman).

The explanations here given of the malaxation and stinging of the prey are purely physiological, but it is not at all certain that such explanations are applicable to the entire behavior cycle of the solitary wasp. Before enquiring into this matter, it will be advisable to sketch very briefly the behavior of a typical Sphex as a paradigm of the whole group of Sphecoids and solitary Vespoids. The female Sphex, after mating, digs in sandy soil a slanting or perpendicular tunnel and widens its end to form an elliptical chamber. She may thereupon close the entrance, rise into the air and fly in undulating spirals over the burrow, thus making what is called a "flight of orientation," or "locality study," because it enables her to fix in her sensorium the precise position of the burrow in relation to the surrounding objects, so that she may find the spot again. Then she flies off in search of her prey, which is a particular species of hairless caterpillar (Fig. 20). When it is found, she stings it into insensibility, malaxates its neck, while imbibing the exuding juices, and drags it or flies with it to the entrance of her burrow. Here she drops her victim and, after entering and inspecting the burrow, returns and takes it down into the chamber, glues her egg to its surface and closes the burrow by filling it with sand or detritus collected from the surrounding soil (Figs. 21 and 22). As soon as the next egg matures in her ovaries she proceeds to repeat the same behavior cycle at some other spot. In the meantime the provisioned egg hatches, and the

FIG. 21
Sphex procerus carrying chips of wood to throw into the burrow at the left of the figure. (Photograph by Prof. Carl Hartman).

FIG. 22
Burrow of *Sphex procerus* in section, showing filling of débris in the tunnel and the paralyzed sphinx moth caterpillar in the cell, with the egg glued to its side. (Photograph by Prof. Carl Hartman).

larva, after devouring the helpless caterpillar, spins a cocoon, pupates *in situ* and eventually emerges as a perfect Sphex.

Some of our species of Sphex actually tamp down the filling of their burrows with a small, carefully selected pebble, held in the mandibles and used as a hammer or pestle (Fig. 23). This

FIG. 23
Sphex urnarius using a selected pebble to pound down earth over burrow. (After G. W. and E. G. Peckham).

astonishing behavior, which has been carefully observed by no less than nine investigators (Williston, Pergande, Geo. W. and E. G. Peckham, Hartman, Hungerford and Williams, and Phil. and Nellie Rau) can hardly be reduced to simple physiological reflexes. The same would seem to be true of the orientation flight and return to the burrow and the fact that some species of Sphex provide the egg with a single large caterpillar, others with several small caterpillars, but in all cases with just enough food to enable the larva to grow to the full stature of a normal individual of its species. The question also arises as to the proper interpretation of the peculiar predilection of the wasp for a particular species of prey. This seems to be the more inexplicable, because experiment has shown that the larva can be successfully reared when some very different insect is substituted for the species which it habitually devours. As I am emphasizing the rôle of nutrition in these lectures, I shall digress somewhat on this question of food specialization and in order to bring the matter before you as vividly as possible recast the behavior of Sphex in the form of a tragic drama in three acts, with the following brief synopsis:

Act I. A sandy country with sparse vegetation inhabited by caterpillars and other insects. Time, a hot, sunny day in early August. Scene 1. Miss Sphex arrayed in all the charm of maidenhood being courted by Mr. Sphex. Wedding among the flowers. Scene 2. Mrs. Sphex deserted by her scatter-brained spouse settles down and excavates a kind of cyclone-cellar. She closes its door and leaves the stage.

Act II. Scene 1. Same as in Act I. Mrs. Sphex, hunting in the vegetation, finds a caterpillar, struggles with it, stings it and gnaws its neck till it lies motionless. Scene 2. She drags it into the cellar and placing her offspring on it behind the scenes, returns and at once leaves the stage after locking the door, amid a storm of applause.

Act III. Scene 1. Interior of Mrs. Sphex's cellar. Baby Sphex slowly devouring caterpillar till only its skin remains. Scene 2. Baby Sphex, now a large, buxom lass, weaves an elaborate nightgown for herself and goes to bed as the curtain falls.

As a work of art this drama is defective, because the climax, the stinging of the caterpillar, falls in the early part of the second act, and because the heroine leaves the stage soon afterwards for good, as if she had been suddenly taken ill and had to substitute her drowsy offspring to perform the whole third act. Still this is the sequence in which the drama is related by all the observers, and I have presented my account in the same manner, because it has undeniable advantages. But see what happens when we rearrange

the drama by making the third or last act the first, and the first and second the second and third, respectively. There is then only one heroine who holds the center of the stage throughout the performance. We witness her gradual growth and development from infancy during the first act, her wedding, desertion and cellar-excavating exploits during the second, and the thrilling chase, stinging and entombment of the hereditary victim in the third act.

I have just committed the unpardonable sin of humanizing the wasp, but being desirous of making my point perfectly clear, I am going to do something still more scandalous and ask you for a moment to vespize the human being. Suppose that the human mother were in the habit of carefully tying her new-born baby to the arm-pit of a paralyzed elephant which she had locked in a huge cellar. The baby—we must, of course, suppose that it is a girl baby—is armless, legless and blind, but has been born with powerful jaws and teeth and an insatiable appetite. Under the circumstances she would have to eat the elephant or die. Supposing now that she fed on the elephant day after day between naps till only its tough hide and hard skeleton were left, and that she then took an unusually long nap and awoke as a magnificent, winged, strong-limbed amazon, with a marvellously keen sense of smell and superb eyes, clad in burnished armor and with a poisoned lance in her hand. With such attractions and equipment we could hardly expect her to stay long in a cellar. She would at once break through the soil into the daylight. Now suppose she happened to emerge, with a great and natural appetite, in a zoological garden, should we be astonished to see her make straight for the elephant house? Why, she would recognize the faintest odor of elephant borne to her on the breeze. She would herself be, in a sense, merely a metabolized elephant. Of course, we should be startled to see her leap on the elephant's back, plunge her lance into its arm-pit, drag it several miles over the ground, hide it in a cellar and tie her offspring to its hide.

The point I wish to make is this: We have all along in our accounts treated the life-history of the insect as that of two individuals in such a manner as to obscure or obliterate the experience of the individual. We begin with the full-fledged insect descending from the blue, and then describe her behavior as if it were a pure inheritance or improvisation. But when we describe her activities as those of a single individual from the beginning of her development to death, we find that the adult female, before she begins to make and provision her nest, has probably learned something from her long and intimate larval contact with the environment. For months she has inhabited a chamber like the one she

will excavate or build for her own progeny, for days she has been devouring a particular species of caterpillar and she has even dug a sufficient distance through the soil to be familiar with its properties. She possesses, therefore, a certain amount of acquaintance with soil and with caterpillars. That this should persist as memory is not only possible but extremely probable when we consider that the central nervous system of the larva passes without profound change into that of the adult wasp and that the latter shows unmistakable evidence of possessing a remarkable memory when she makes such locality studies as have been described and returns to her nest or prey after an absence of several hours or even days. We are also enabled to understand why the wasp confines her attention to a particular species or even to one sex of a species while searching for her prey, and why the malaxation or mutilation of the prey may be regarded as a reminiscent act of feeding. In brief, all those activities of the adult wasp which are partly or wholly interpretable as a repetition of larval behavior, may be attributed to memory—not in the sense of recollection, with its feeling of "pastness," but of mere sensory and motor memory, the *memoria sensitiva* of scholastic writers, or the "associative memory" of comparative psychologists.

But there still remain unexplained the more striking activities, those performed for the first time in the wasp's life-history, namely the cocoon-spinning of the larva, the making, closing and opening of the nest, oviposition, etc. No doubt these acts are all initiated by stimuli, partly internal and partly external, such as hunger, the tension of accumulated silk in the spinning glands, of eggs in the ovaries, hormones in the blood, and olfactory and tactile impressions from contact with the caterpillar and the soil, but the reeling off of the train of these purposive responses must depend on inherited dispositions in some way correlated with the structure of the nervous and muscular apparatus. And we must suppose that these dispositions somehow represent the experience of untold former generations of wasps. We are, however, unable to form any adequate conception of the extent of the racial experience of the solitary wasps as a group and therefore of the amount of condensation or syncopation with which it is epitomized in the behavior of the individual wasp, and this disability on our part is largely responsible not only for the old supernatural conceptions of instinct but also for theories like those of Bergson, the Neodarwinians and the mutationists.

We may now turn to the evolution of social behavior, which, in diverging lines of descent, has been gradually evolved and perfected from such a method as that employed by most of the

Sphecoids and non-social Vespoids. This method, which consists in rapidly accumulating an amount of prey sufficient to enable the young to develop to maturity and of then closing the cell before the egg has hatched, we may designate, with Roubaud, as "mass provisioning." We have seen that in some cases the mother wasp stores a single large insect, in others a number of smaller ones, before closing the cell. If in the latter case the accumulation of the prey is delayed on account of scarcity or inclement weather, the egg, which has been glued to the first small insect captured, hatches before the mother wasp has succeeded in collecting a sufficient supply for the growth of the larva. She is therefore reduced to feeding her offspring from day to day, *i. e.*, to what Roubaud calls "progressive provisioning," a method which is seen in certain species of Sphex and Lyroda (*S. politus* and *L. subita*, according to Adlerz) and probably also in *Aphilanthops frigidus*, according to my observations. But the best examples may be observed among the digger-wasps of the family Bembicidæ, on which we possess a number of valuable studies by Wesenberg-Lund, Bouvier, Marchal, the Peckhams, Hartman, Riley, Melander, Ferton, Parker, Adlerz, the Raus, etc. While our large cicada-killer (*Sphecius speciosus*) provisions its burrows with a single cicada, lays an egg on it and closes the cell, thus practicing typical mass provisioning, some other Stizinæ and many species of Bembix and allied genera proceed in a different manner. These insects live in open, sandy places, often in rather populous and compact congregations, though each female makes and provisions her own burrow. The prey of each species of Bembix consists of the common two-winged flies of her environment, without regard to the species. They are stung to death but not mutilated. After the burrow is excavated the wasp kills a small fly and after dislocating one of its wings, places it on its back on the floor of her cell and attaches her egg to its sternum. The dislocation of the wing is supposed by Ferton to be a device for preventing the fly from being turned over by the very delicate young larva and thus insuring it against injurious contact with the rough, sandy floor of the cell. The mother collects flies and brings them into the burrow from day to day, actually increasing the size or number of the victims as they are needed by the growing and increasingly voracious larva. At least one European species of Bembix (*B. mediterraneus*), according to Ferton, lays her eggs on the floor of the cell before bringing in any flies. Instead of flies, the species of Bicyrtes and Stizus provision their young progressively with bugs or leaf-hoppers, and one of our species (*Microbembex monodonta*), according to Hartman, Parker and the Raus, feeds its young on all sorts of small, dead

and dried insects (grasshoppers, beetles, flies, mayflies, ants, etc.) picked up from the soil.

Among several of the solitary Vespoids we find very similar conditions and these are of more immediate interest to us because this group of insects has evidently given rise to the true social wasps. The numerous species of Eumenes and Odynerus (Fig. 24), as well as the allied genera, either excavate their burrows in the ground, or take possession of the tubular cavities of twigs or the interstices of walls, or construct exquisite mud cells above ground on the surfaces of rocks, trees or walls. After the cell is completed the egg is hung by a filament from its ceiling. Numerous small, smooth, paralyzed caterpillars are then brought in and the cell is closed. This is, of course, typical mass provisioning. But Roubaud has observed some very significant modifications of the process in certain Congolese species. Of one Odynerus (*O. tropicalis*) he gives the following account: "This little Odynerus does not

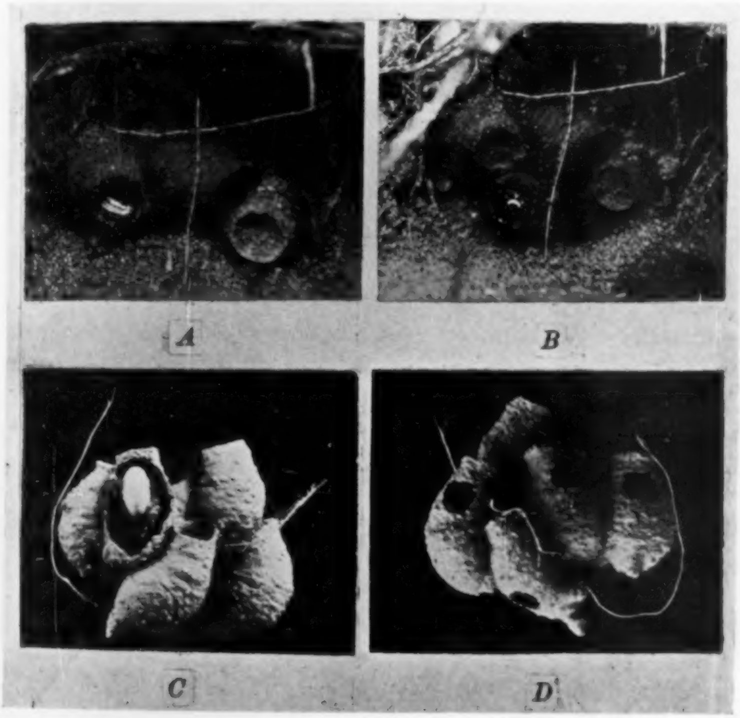


FIG. 24

Four stages in the mud nest of *Odynerus dorsalis*. *A*. Showing one cell open and being stored with small caterpillars; *B*. Nest on the following day, showing wasp resting in a new cell made on the previous afternoon. *C*. Nest with one cell opened to show the wasp larva feeding on caterpillars; *D*. Same nest, showing holes made by the escaping wasps. (After Carl Hartman).

provision its cells with prey amassed in advance, but nourishes its larvæ from day to day, with small, entire, paralyzed caterpillars, which are always given to the larva in very small numbers, till its growth is completed. The egg is never walled up in the cell with provisions hastily amassed. The wasp, to judge from what I have been able to observe of its educative procedure, after having laid her egg, watches it within the cell after the manner of the higher species of Synagris till it hatches. As a rule, prey is brought to the egg only at the moment of hatching or a little before, and usually a single small caterpillar, rarely two and never three, is found placed at the disposal of the just-hatched larva. *Pari passu* with the growth of the latter the prey is renewed, but always in small numbers. Sometimes the larva may be seen fasting in the cell while the mother wasp is away in search of prey. Finally, it is only after its feeding has been completed that the larva is immured in the cell. In no case did I observe in closed cells containing larvæ the slightest trace of provisions." Even more interesting are the species of Synagris referred to in this quotation. In several of them Roubaud found the following conditions, representing transitions from mass to progressive provisioning:

The female of *Synagris spiniventtris* (cited as *callida* by Roubaud) and *callida* (cited as *sicheliana*) under normal conditions, *i. e.*, when food is abundant, lays an egg in her mud cell, fills it in the course of a few days with small paralyzed caterpillars, sometimes to the number of 60 (!) and then closes it, thus adopting the usual or "banal" method of mass provisioning. When, however, owing to seasonal or climatic conditions, caterpillars are scarce, the female, after ovipositing and guarding the egg for some time, collects a meager provision of small caterpillars for the hatching larva and while it is growing, continues to feed it in the same manner. After the larva has attained three fourths of its adult size, the wasp immures it in its cell with the last supply of provisions. As Bequaert remarks, "in *S. spiniventris*, progressive provisioning is still optional, and one observes all the transitional stages between this behavior and the normal provisioning in mass. The mother wasp shows great skill in adapting her habits to the external conditions." According to Roubaud another species of Synagris (*S. cornuta*), proceeds a step further (Figs. 25 and 26). The female, after completing her earthen cell, lays an egg on its floor and when the larva hatches feeds it from day to day with pellets made of a paste of ground up caterpillars. This is precisely the method employed by the social wasps in feeding their larvæ!

FIG. 25
Mud nests of *Synagris cornuta* on the thatching of a native hut in the Congo. "Some of these nests show very distinctly the short neck with its slightly widened opening curved to the side and downwards. Such a chimney is built at the entrance of the cells containing eggs or larvæ still nursed by a female." (After J. Bequaert from a photograph by H. O. Lang).

A step in the direction of the social wasps seems also to have been taken by a small group of solitary Vespoids, allied to the Eumeninæ, namely the Zethinæ. These insects, which have been studied recently in Brazil by Ducke, in British Guiana by Howes and in the Philippines by F. X. Williams, have abandoned the use of earth as nest material and employ instead small bits of leaves or moss (Fig. 27). With such vegetable material *Zethus* constructs a beautiful nest with one or several tubular cells, and therefore approaches the social wasps which make their nests of paper, a substance consisting of fine particles of wood agglutinated with an oral secretion. The egg is laid loosely in the bottom of the cell and, according to Williams' account of the Philippine *Zethus cyanopterus,* the larva is fed from day to day on small caterpillars, which have been in part eaten by the mother. She faithfully guards the larva and, while it is small and there is still ample room, sleeps in the cell. She closes the latter as soon as the larva is full grown and proceeds to build another.

Each of these cases of progressive provisioning may be regarded as a very primitive family, or society, reduced to its simplest terms, *i. e.*, to a mother and her single offspring. The seasonal or local conditions of the environment, in so far as they affect the abundance or scarcity of prey, have led on the one hand to mass provisioning and therefore to an exclusion of the mother from contact with her growing offspring, and on the other to an establishment

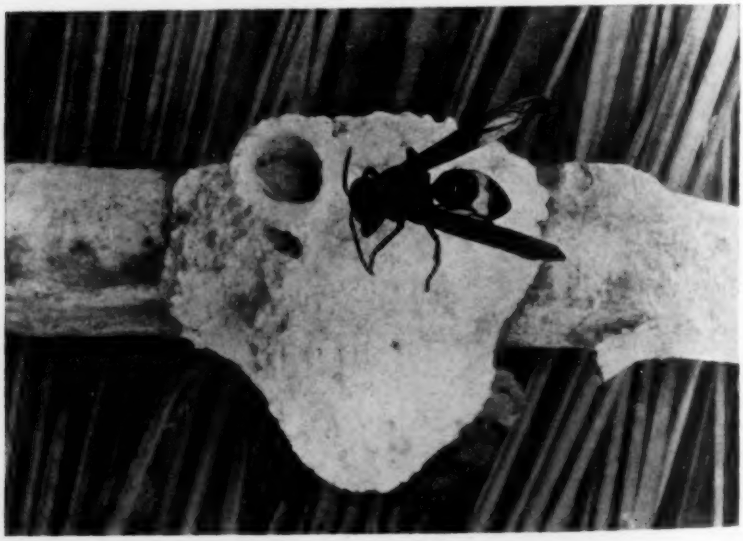


FIG. 26
Mud nest of *Synagris cornuta* var. *flavofasciata* with mother wasp. (After J. Bequaert from a photograph by H. O. Lang).

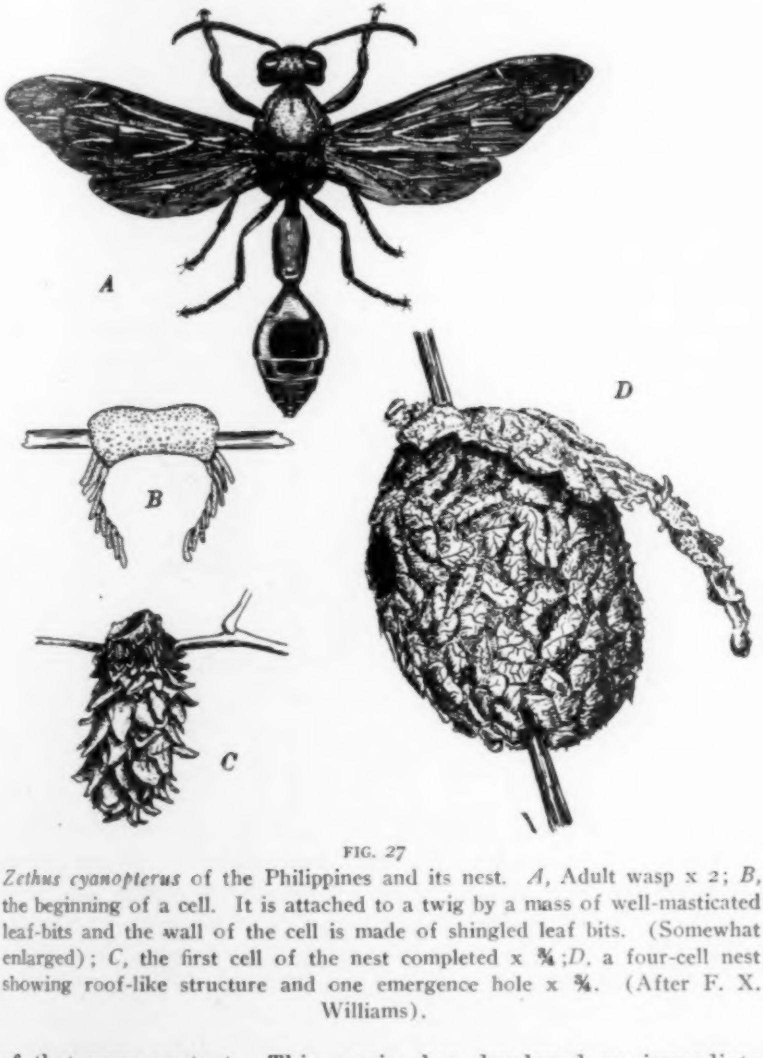


FIG. 27
Zethus cyanopterus of the Philippines and its nest. *A*, Adult wasp x 2; *B*, the beginning of a cell. It is attached to a twig by a mass of well-masticated leaf-bits and the wall of the cell is made of shingled leaf bits. (Somewhat enlarged); *C*, the first cell of the nest completed x ¾; *D*, a four-cell nest showing roof-like structure and one emergence hole x ¾. (After F. X. Williams).

of that very contact. This, again, has developed an immediate interest of the mother in her young comparable with what we observe in many birds. Probably this interest is aroused and sustained in the mother wasp by simple, pleasurable, chemical (odor) or tactile stimuli emanating from the egg and larva, but whatever be the nature of the stimuli involved, I believe that we shall have to admit that the egg and the larva have acquired a "meaning" for the mother wasp, and so far as the egg is concerned, this seems to be true even in the species that practice mass provisioning. We noticed that many solitary Vespoids (Eumenes, Odynerus), before they bring in their prey, carefully attach the egg by a string

to the ceiling of the cell. This singular performance has been variously interpreted. Fabre and others regard it as a device for preventing the delicate egg from being crushed by the closely packed and sometimes reviving prey, on the same principle that in a crowded room an electric light bulb attached by a cord to the ceiling would be less easily crushed than one rigidly fixed to the walls or the floor. Others regard the filament as a device for keeping the egg free from the occasionally very damp walls of the cell. Ferton has recently shown that *Bembix mediterraneus* glues its slender egg to the floor of the cell in an erect position and with the base carefully supported by a cluster of large sand-grains (Fig. 28 A), and that *Stizus errans* glues its egg in a similar position

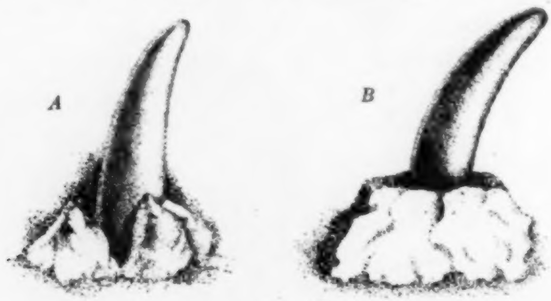


FIG. 28

A. Egg of *Bembix mediterraneus* with its base supported by a cluster of large sand-grains. *B.* Egg of *Stizus errans* glued to the upper surface of a carefully selected pebble. (After C. Ferton).

to the top of a small, carefully selected pebble placed on the floor of the cell (Fig. 28 B). Parker's description of the egg of our *Microbembex monodonta* seems to indicate a condition similar to that of *B. mediterraneus*. In all these cases we seem to have an arrangement for keeping the very easily injured egg as free as possible from contact with the rough, sandy walls of the burrow. But even the Sphecoids and Psammocharids, which practice mass provisioning, attach the egg to a particular part of the victim and in such a position that the hatching larva can attack it at its most vulnerable point. Ferton, especially, has made a very interesting study of this type of behavior.

The following facts also indicate very clearly that the mother wasp may be aware, not only of sexual differences among her own eggs but also of the differences in the amount of food required by the resulting larvæ. Bordage, while investigating the Sphecoids of the Island of Réunion, found that three of the species, *Pison argentatum, Trypoxylon scutifrons* and *T. errans,* could be readily induced to make their cells in glass tubes placed between the

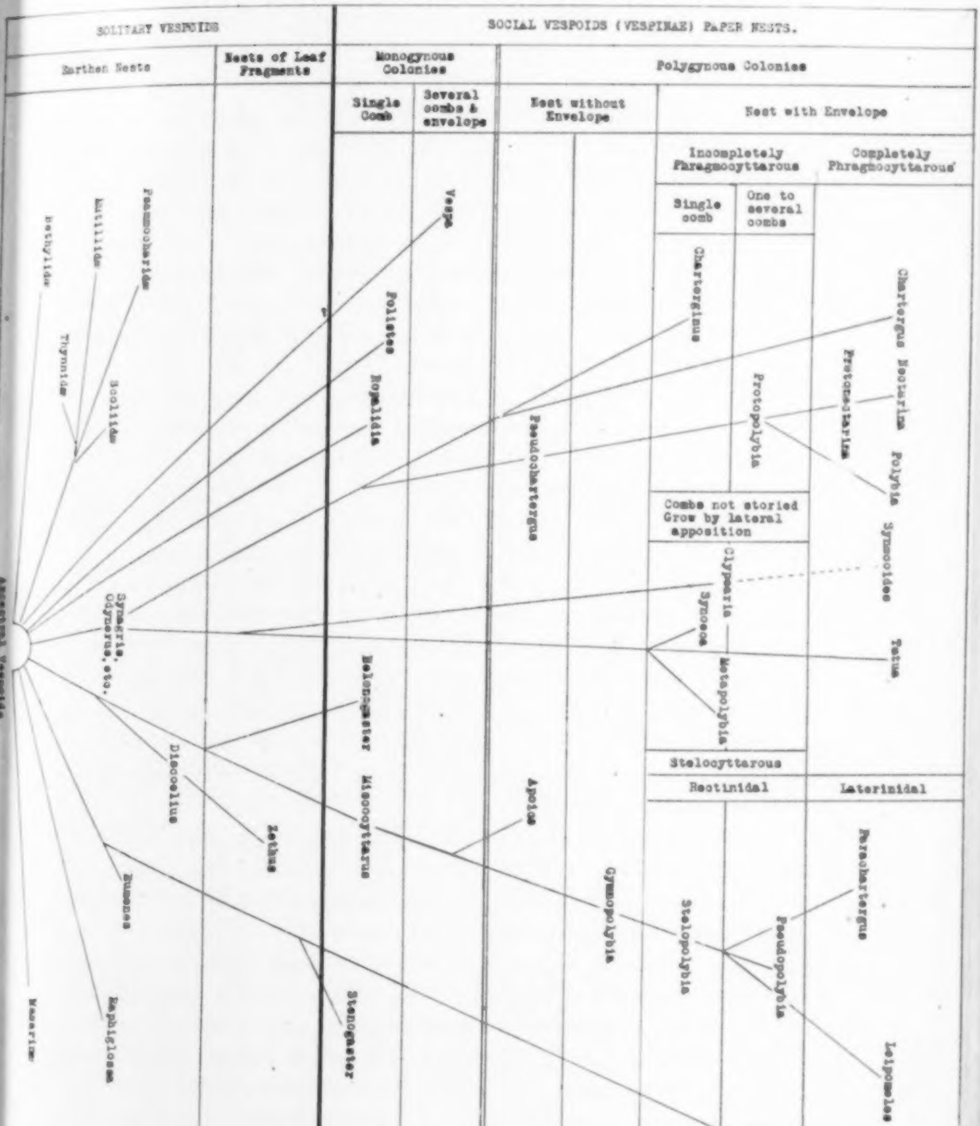


FIG. 29

Phylogenetic tree of the various genera and families of Vespoids. (After Ducke, with modifications).

pamphlets of his library. The Pison, under natural conditions, builds elliptical clay cells and provisions them with spiders, whereas the species of Trypoxylon nest in hollow twigs and the interstices of wall but use the same kind of prey. All these species adapted themselves to the glass tubes in the same manner. Each of them plugged the end of the tube with clay and divided the lumen into successive cells by building simple clay partitions across it. After the cells had been provisioned, Bordage observed that the first of them were longer by half a centimeter and contained more prey than those provisioned later, and he was able to show that the larvæ in the larger, more abundantly provisioned cells produced female, the others male wasps. Similar observations have also been published by Roubaud on the Congolese *Odynerus* (*Rhynchium*) *anceps*, which makes clusters of straight, tubular galleries in clay walls and divides each gallery into several cells by means of clay partitions. In this case also the first cells are much longer than the later, though there is no difference in the quantity of small caterpillars allotted to the different eggs. But Roubaud was able to prove experimentally that even when the amount of food is so greatly decreased that the larvæ produce adult wasps of only half the normal size, their sex is nevertheless in no wise affected. It would seem therefore that the mother wasp must discriminate between the deposition of a fertilized, female-producing and that of an unfertilized, male-producing egg, and regulate the size of the cell and in some instances also the amount of provisions accordingly.

In the accompanying diagram (Fig. 29), taken from Ducke but somewhat modified, I have indicated the hypothetical family tree of the solitary and social Vespoids. The genera below the heavy horizontal line are solitary, and among them Eumenes and Odynerus seem to be nearest to the original ancestors, because they are very similar to the social forms in having longitudinally folded wings and in other morphological characters. It will be seen that there are six independent lines of descent to the social forms above the heavy line and that the genera plotted at different levels represent various stages of specialization as indicated by the nature of the materials and types of structure of the nests. With the doubtful exception of a few Stenogastrinæ, all the social wasps make paper nests consisting wholly or in part of one or more combs of regular hexagonal cells, in which a number of young are reared simultaneously.

(*To be continued*)

THE PROGRESS OF SCIENCE[1]

INTERNATIONAL COOPERATION IN INTELLECTUAL WORK

STEPS have been taken toward the formation of a committee of the League of Nations on international cooperation in intellectual work. Eleven of the twelve members have been appointed, and as none of them is an American, it is expected that the vacancy will be offered to an American scholar.

The committee so far chosen consists of Henri Bergson, the French philosopher and author of "Creative Evolution"; Madame Curie, the Polish discoverer of radium; Albert Einstein, the German mathematician who propounded the theory of relativity; Gilbert Murray, professor of Greek at Oxford; Miss Bonnevie, professor of zoology at Christiania; D. B. Bannerjee, professor of political economy at Calcutta; A. De Castro, of the medical faculty of the University of Rio de Janeiro; J. Destree, former minister of science and art in the Belgian cabinet; G. De Reynold, professor of French literature at Berne; F. Ruffini, professor of ecclesiastical law at Turin, and L. De Torres Quevedo, director of the electro-medical laboratory of Madrid.

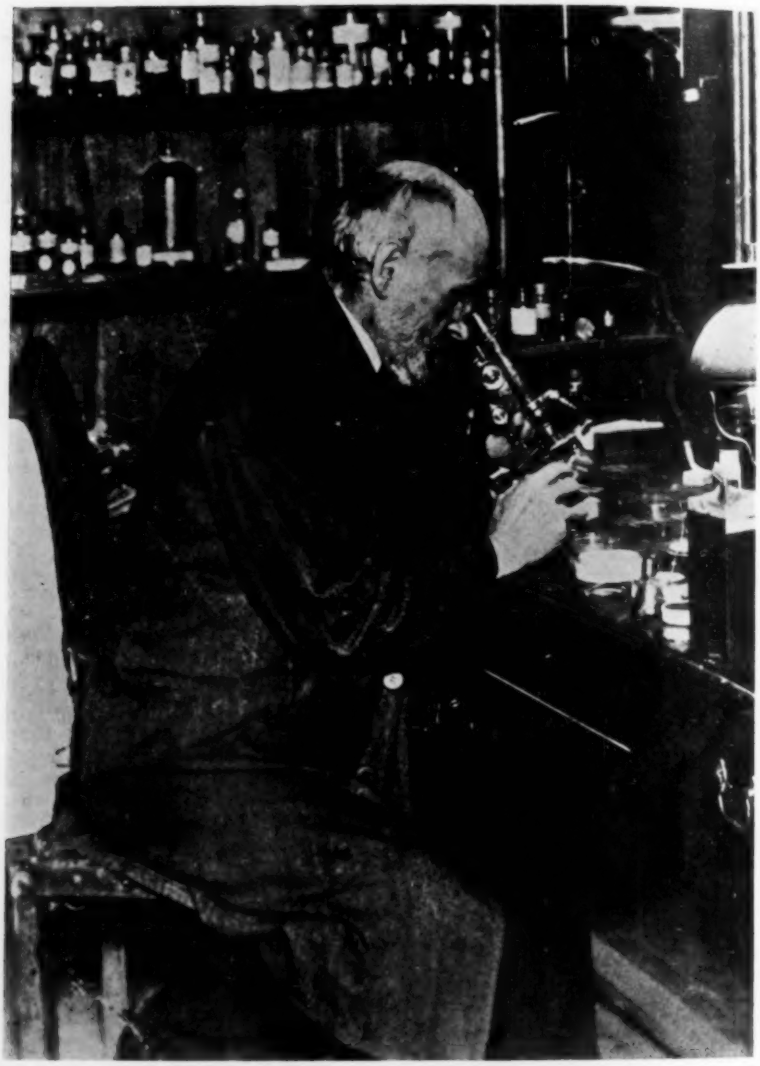
The first meeting of this committee is set for August 1, and a prominent position on the program of work outlined is given to measures that will facilitate the interchange of scientific information and the development of higher education in the countries participating.

With regard to the organization of intellectual work from an international standpoint the report adopted by the council of the League of Nations when the committee on international cooperation in intellectual work was organized says:

> We are all agreed that the League of Nations has no task more urgent than that of examining these great factors of international opinion—the systems and methods of education and scientific and philosophical research. It would be unthinkable that the league should endeavor to improve the means of exchange of material products without also endeavoring to facilitate the international exchange of ideas. No association of nations can hope to exist without the spirit of reciprocal intellectual activity between its members.
>
> For example, it is clear to all how much the league would benefit by any new measures which by establishing a more definite parallelism between the diplomas of the various countries and a more frequent exchange of chairs between professors of various nationalities would lead to a more active interchange of teachers and students between nations. A still greater benefit would result from measures which permitted a more rapid and more accurate communication of all work undertaken simultaneously in the field of scientific research in various parts of the world.
>
> There is no question of detracting from the originality of national workers whose very diversity is essential for the general progress of ideas. On the contrary, the object is to enable each of these national thinkers to develop his ideas with greater force and vitality, by making it possible for him to draw more fully upon the common treasure of knowledge, methods and discoveries.

As a part of the work of the League of Nations, a "Handbook of International Organizations" has recently been issued, which lists 315 societies, associations, bureaus, committees and unions, all of them international in some aspect. It is an interesting collection of religious, scientific and other sorts of organizations, the international association interested in lawn tennis being listed with the entomological, meteorological

[1] Edited by Watson Davis, Science Service.



PROFESSOR SANTIAGO RAMON Y CAJAL

The distinguished Spanish histologist who retires from the chair of histology and pathological anatomy at the University of Madrid on reaching his seventieth year.

and other scientific societies. Such a directory is a necessary preliminary of the activities of the committee on international cooperation in intellectual work.

CALENDAR REFORM

Reform of the calendar has been much discussed during the past decade or more, for the inconveniences and inconsistencies of the present calendar are obvious.

The two schemes which are receiving the largest amount of attention are the international fixed calendar plan and the Swiss plan.

The former, first publicly proposed by Moses B. Cotsworth of Vancouver in 1894, provides for thirteen months in the year, with twenty-eight days to the month, every date being attached to the same day of the week in every month. New Year's Day is a zero day called January 0, and is a full holiday. The extra day in leap year is a similar holiday inserted as July 0. The extra month, which, of course, does not add to the actual length of the year, is introduced between June and July, and is called "Sol." Easter is to be fixed by the Christian churches on some date between March 21 and April 26, this stabilizing an event whose drifting causes inconveniences and losses in business and social life.

The Swiss plan has been advocated largely by astronomers. It also sets aside each New Year's Day and each leap-year day as independent legal holidays. The other 364 days are divided into four quarters of 91 days each, each quarter containing one month of 31 days and two months of 30 days, thus keeping twelve months as at present.

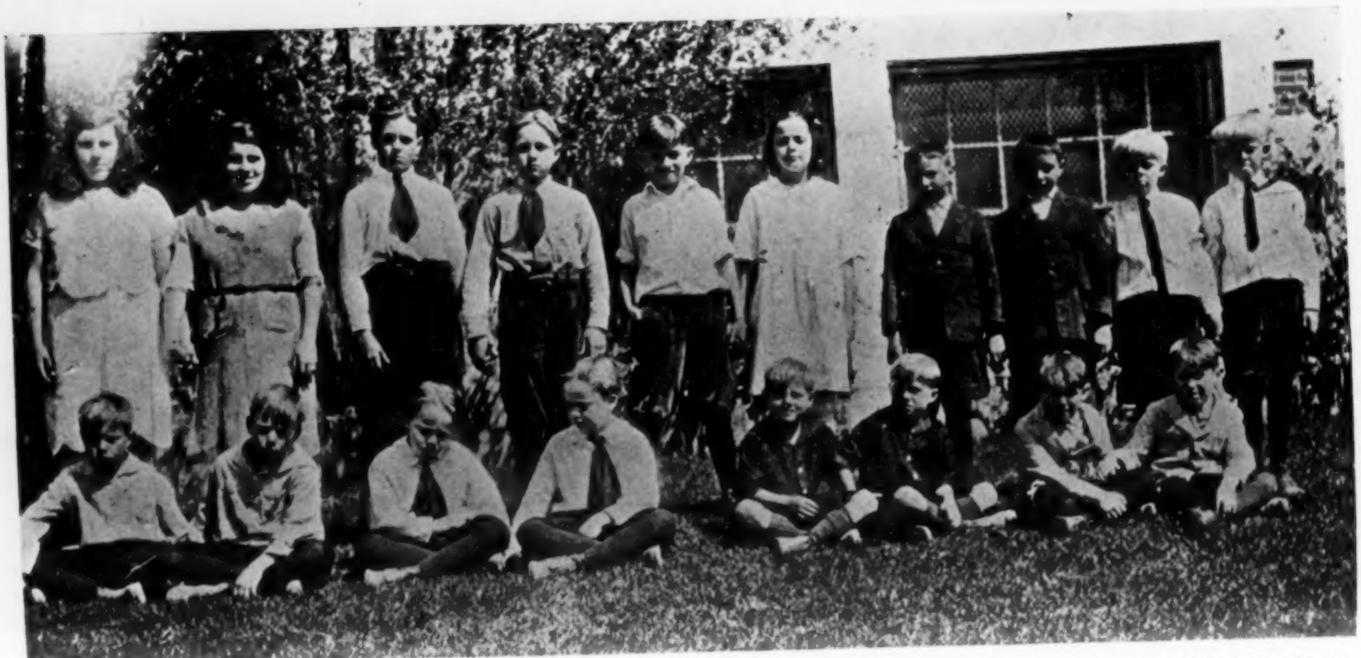
The international fixed calendar plan recently received the unanimous approval of a convention held in Washington by those interested in calendar reform. The American section of the International Astronomical Union, after considering both the Swiss plan advocated by its committee on calendar reform and the fixed calendar plan, recently refused to take action on the matter.

The question of calendar reform was taken up at a meeting of the International Association of Academies held in St. Petersburg in 1913, and a committee was appointed on that occasion "to study questions relative to the unification and simplification of the calendars and the fixing of the date of Easter." This committee would have made a report in 1916, but for the war. Another discussion of this subject took place at the International Geographical Congress held in Rome in 1913. In June of the same year the World Congress on International Associations, which met at Brussels, passed a resolution urging the governments of the world to adopt a universal calendar. Three of the International Congresses of Chambers of Commerce have given expression to the same desire. Finally, just before the outbreak of the world war, the International Congress on the Reform of the Calendar held its sessions at Liège, and not only agreed to urge the adoption of a universal and improved calendar but also made plans for a formal conference, which was to have been convoked in Switzerland at the invitation of the Swiss government. but was never held.

In the future there may come a conference of nations that will adopt a new and more logical calendar as easily as standard time was established by an international conference at Washington about forty years ago.

INVISIBLE SUN-SPOTS

Dr. George Ellery Hale, director of the Mount Wilson Observatory, has announced the discovery of invisible sun-spots. In 1908 Dr. Hale found that a sun-spot is a great whirling storm, similar to a terrestrial tornado, but on a gigantic scale, often vastly larger than the earth. The ex-



Wide World Photos

TWINS ATTENDING A LOS ANGELES PUBLIC SCHOOL

pansion of the hot solar gases, caused by the centrifugal action of the whirl, cools them sufficiently to produce the appearance of a dark cloud, which we call a sun-spot. If this cooling is not great enough to produce a visible darkening of the surface, the whirling storm may still be present, though invisible to the eye. Such invisible whirls have now been detected by their magnetic effect on the light emitted by the luminous vapors within them.

Magnetic fields in visible sun-spots were first found by Dr. Hale in 1908. They are due to the whirl of electrified particles in the spot vortex, just as the magnetic field of an electromagnet is produced by the whirl of electrons through its wire coils. The magnetic field in a sun-spot is recognized by the effect it produces on the lines in the spectrum. A line due to iron vapor, for example, is split into three parts by the powerful magnetic field in a large spot. In a very small spot, where the magnetic field is much weaker, the line is not split up but is merely widened.

Invisible spots were discovered by exploring promising regions of the sun where signs of disturbance, such as faculæ or clouds of calcium vapor, are present. A special polarizing apparatus moves back and forth across the slit, while the iron line is watched through a very powerful spectroscope. The presence of a weak magnetic field, showing the existence of an invisible spot, is betrayed by a slight oscillation of the corresponding part of the line, caused by its widening successively to right and left as the polarizing apparatus oscillates over the slit.

Ten invisible spots have been found since November by this method by Messrs. Hale, Ellerman and Nicholson with the 150-foot tower telescope and 75-foot spectroscope on Mount Wilson. Some of them foreshadow the birth of a visible spot, which finally appears to the eye several days after the first indications of the whirl have been found. Others correspond to the period of decay, and permit a spot to be traced for some time after it ceases to be visible. In other cases the invisible spot never reaches maturity, which means that the cooling produced by expansion never becomes great enough to produce perceptible darkening of the sun's disk.

TWINS AGAIN

THE popular interest in twins seems to have considerable vitality. Every year brings into the public press and magazines some news item or article concerning multiple births. Just a year ago the whole country was stirred by the announcement of the birth of quadruplets in New Haven, Connecticut. (By the way, they have all passed their first birthday). Recently the newspapers carried full accounts of the death of the conjoined Blazek twins of Chicago, recalling the older days when the Siamese twins were in the prints and broadsides. Now comes Los Angeles, with photographic evidence that in one school building are enrolled as many as nine pairs of twins. And on the heels of the City of Angels comes the City of Churches, Brooklyn, with a contingent of ten pairs of twins, all attending Public School 77. Some statistician may soon find for us a rural school in which 30 per cent. or more of the entire enrollment are twins.

After all, twins are more common than we ordinarily suppose; and our interest in them far exceeds their rarity. Wappeus found that more than one child was born in 1.17 per cent. of 20,000,000 cases of labor. Pre-war Prussian statistics showed that twins occurred once in 89, triplets once in 7,910, and quadruplets once in 371,125 labors. This does not, of course, mean that all survive. The hazards of birth and of both prenatal and neonatal life are greater for plural than for singular pregnancies.

Wide World Photos.

TWINS ATTENDING A BROOKLYN PUBLIC SCHOOL

A comparison of international statistics appears to indicate that multiple pregnancy is more common in cold than in warm climates. We should, therefore, not be surprised that Brooklyn has a higher record than Los Angeles! If the figures quoted by Williams can be trusted, Russia is in this special sense over twice as prolific as Spain. In Russia, multiple birth occurred once in 41.8 labors, as compared with once in 113.6 labors in Spain.

The accompanying photographs raise some interesting questions in regard to the distribution of sex among twins. In the aggregate 38 children are pictured, of which 18 are boys, and 15 of these happen to be in the California group. This approximates the equal or nearly equal divisions which we should expect when all the twin boys and girls in the land are counted. But there are other interesting questions. Suppose the Brooklyn group were playing helter-skelter in the school yard. Would it be possible for a stranger to select all the pairs of twins and match each to the appropriate co-twin? It happens that there is such a predominance of same-sexed similar twins that this could be readily done. Suppose, however, that the Los Angeles group were scrambled in the same manner, would it be possible by inspection to pair off all the twins? This is doubtful. It would be particularly difficult to make a confident decision in the case of the four children in the back row, beginning with the third from the left. This difficulty brings out clearly the fact that there are marked differences as well as resemblances between twins. We, of course, always expect at least some degree of family resemblance, but even this may not be obvious to ordinary observation.

The problem of twin resemblance is discussed by Dr. Arnold Gesell, professor of child hygiene, Yale University, in two recent articles on "Mental and Physical Correspondence in Twins," published in the April and May numbers of THE SCIENTIFIC MONTHLY. He describes a remarkable case showing extensive, detailed correspondence both in physical and psychological characters in a pair of gifted girl twins. He notes, however, that pathological deviation in the process of twinning may produce monstrous degrees of individual difference even in twins derived from a single egg. Biologists recognize two major classes of human twins: (1) Duplicate or uni-oval, who are always of the same sex, closely resemble one another and presumably originate from one fertilized egg. All but one of the Brooklyn group apparently belong to this class; (3) Fraternal or bi-oval twins, who may or may not be of the same sex, who show ordinary family resemblance and are in all probability derived from two separate eggs. Two pairs, at least, of the Los Angeles twins belong to this category. Statistics based on a large series of cases indicate that one pair of twins in every three pairs born consists of a boy and a girl, and that about two out of every five pairs in which the members are of the same sex are uni-oval in origin. Since there are only two pairs of two sexed or "pigeon" twins in the combined group of 18 pairs in the photographs, we must again be cautious in drawing general deductions from the pictures.

Do resemblances decrease with age? Such a deduction might be drawn from the Los Angeles photograph, but it would not be well supported by the facts. Two pairs of twins of the fraternal type happen to include the older children in this group, and resemblances are less marked in this type. The fundamental correspondences, both physical and mental, to be found in twins unquestionably have a hereditary basis and are only in a secondary way affected by time and experience. Time may, by a cumulative process, accentuate a differentia-

tion of twin personalities dating from childhood or youth, but the primary differences and resemblances are due to original nature. The study of twins does not shake our confidence in the importance of education and surroundings, though it impresses upon us at every turn the decisive significance of inheritance and the lawfulness of the mechanics of development. The popular interest in twins is a wholesome one, because twins are a key to many biological and psychological principles at the basis of human welfare.

SCIENTIFIC ITEMS

We record with regret the death of Henry Marion Howe, emeritus professor of metallurgy in Columbia University; of John Sandford Shearer, professor of physics at Cornell University; of George Simonds Boulger, the English writer on botany; of Ernest Solvay, known for his process for the manufacture of soda; and of C. L. A. Laveran, of the Pasteur Institute.

Among five busts unveiled in the Hall of Fame for Great Americans at New York University on May 20 was one of Maria Mitchell, the gift of her nephew, William Mitchell Kendall, and the work of Emma S. Brigham. President Henry Noble McCracken, of Vassar College, where Miss Mitchell was professor of astronomy from 1865 to 1888, unveiled the bust.

Dr. Ray Lyman Wilbur, president of Stanford University, has been elected president of the American Medical Association for the meeting to be held next year at San Francisco.

The Croonian lecture was delivered before the Royal Society on June 1, by Dr. T. H. Morgan, professor of experimental zoology in Columbia University. His subject was "The mechanism of heredity."

Dr. W. W. Campbell, director of the Lick Observatory, has been elected president of the International Astronomical Union in succession to M. Baillaud, director of the Paris Observatory. The Astronomical Union held its triennial meeting in Rome in May and will hold its next meeting in Cambridge, England.

It is announced that the contest of the will of Amos F. Eno will be settled out of court by the payment of about four million dollars to Columbia University. The 1915 will, which has been twice broken by juries but both times upheld by courts on appeal, gave the residuary estate to Columbia University. The will made bequests of $250,000 each to the Metropolitan Museum of Art, the American Museum of Natural History, the New York Association for Improving the Condition of the Poor, and the New York University. Had the will been broken finally, these institutions would have received nothing. Whether they receive the full $250,000 each under the settlement, or what proportion of the total they receive, is not disclosed. The Society of Mechanics and Tradesmen received $1,800,000 under the 1915 will, and had that will been broken would have received $2,000,000 under an earlier will. This institution could not therefore be called upon to sacrifice anything in order to satisfy the heirs, and will receive the full $1,800,000.

We much regret that there was an error in the inscriptions of the illustrations of the note on *Hesperopithecus* in the last issue of this journal. Fig. 2 on page 589 is the important type tooth, whereas Fig. 1 is the second molar of *Hesperopithecus* which serves to confirm the first of the type.